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ANALYSIS OF TRENCH DRAIN SYSTEMS
BENEATH FOUNDATIONS

A Special Research Problem

Presented to

The Faculty of the School of Civil Engineering
Georgia Institute of Technology

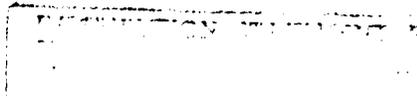


by

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ABSTRACT

This study is an analysis of the performance characteristics of a trench drain system used for foundation dewatering. By the uses of a finite element analysis program the trench drain system performance will be modeled.

Through the use of dimensional analysis techniques the results of the system modeling will be used to prepare a means of predicting the system performance for a wide range of variables.

As an economic concern the trench drain system will be compared with the common blanket drain. This comparison will provide information necessary for the selection of the method most economical for the application.

The trench drain characteristics of primary concern are the total system flow and the maximum free surface height of the water between trenches. The determination of the radius of drawdown for the system is a vital element of the prediction process and is a major portion of the study.

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CHAPTER 1
TRENCH DRAIN SYSTEM

I. Introduction:

Shallow foundations are susceptible to damage and leakage from the hydraulic forces of groundwater. The pressure of water will damage walls, pass into the structure through cracks and holes and contribute to the deterioration of metal, wood and concrete structural members. A structure will not satisfactorily full fill the intention of the owner if water gathers in the basement or garage of the building. A great deal of effort is expended by builders, owners and designers attempting to prevent water from infiltrating a foundation or collecting behind the walls. The most simple solution, as well as the most effective and economical is to properly design the foundation so that water is not present to penetrate the structure.

For a shallow foundation positioned at a moderate depth below a water table the foundation trench drain system is an alternative to expensive water resistant methods of construction. The foundation trench drain system is an application of a very old technique. A trench filled with highly permeable granular material collects water from surrounding, less permeable soil and carries it by gravity flow and slope to a sump or outfall,

where the water can be removed or wasted. Today the flow is usually in slotted pipes within the granular trench. Since the water can be removed from the highly permeable soil more quickly than it can exit the less permeable soil a difference in elevation of the water levels of the two soils is created. This gradient serves to provide continued flow as long as the gradient exists.

The gravity flow method is obviously very easy to implement and generally inexpensive. It does not always work well to dewater or drain a site sufficient to accomplish construction. It is usually not effective to attempt dewatering by gravity flow when (Powers, pg.236):

- a. Soil is a loose granular deposit without plastic fines.
- b. The soil has a high permeability.
- c. There is a proximate source of large recharge to the water table such as a lake or river.
- d. The aquifer is artesian or bounded under a positive head by an impermeable upper surface.
- e. The depth to be dewatered is large so that there will be a high gradient between the water table and the base of the foundation.

If the soil to be dewatered does not have the limiting conditions gravity dewatering still might not be

advisable. The tendency of a soil to hold water is called storage. All soils will retain water by capillary tension while the apparent water table level is drawn down. A soil with a high storage have a surprisingly large amount of water held above the water free surface(Powers, pg.114). Removal of the held water may require energy in the form of pumping.

For this study the trench drain system for dewatering beneath a foundation will be evaluated. The evaluation will be done assuming that construction of the foundation is complete and construction dewatering has lowered the free water surface to below the design final elevation. The trench drain system will maintain the free water surface at the final elevation and not in contact with the foundation.

II. Purpose of the Study:

In this study the characteristics of a trench drain system will be evaluated with the use of the Aral Seepage Program, a finite element analysis program. Under a range of normal variables a trench drain system will be evaluated to determine; (a)the output flow of the system under the different configurations, (b)the range to which drawdown of the water table can be expected and (c)the maximum rise of the free water surface between the trenches.

The results of the finite element analysis will be grouped under dimensional analysis to provide a model for prediction of the characteristics. The predictive method will be effective within the range of variables considered.

Finally a cost analysis of the trench drain system as compared to a blanket drain system. With this information a designer will be able to effectively select the most cost efficient solution to the problem considered if the choice is between the trench drain and the blanket drain system.

CHAPTER 2

PREPARATIONS FOR THE ANALYSIS

I. Introduction:

In preparation for collecting data to analyze the dewatering capacity of a trench drain system planning was necessary to facilitate the assimilation of results. Dimensional analysis, used in presenting the results of this study is briefly reviewed in this chapter.

As with all numeric seepage calculations the area to be dewatered is of critical importance. The size of the cone of depression or the radius of influence is the single most difficult parameter to establish. Many rules of thumb, observations and formulas exist from which the radius of influence is determined in practice. To predict the rate of flow and water table drawdown the radius of influence must be determined. The evaluation of the radius of influence for use with the Aral Seepage Program is reviewed in this chapter.

The Aral Seepage Program, a finite element analysis, used in evaluating the trench drain system of this study was detailed by an earlier study (Pirtle, Appendix A). In preparing for runs of this program several items were noted which amplify the instructions of the user's manual.

11. Dimensional Analysis:

In this study the modeling of a large trench drain system used, for dewatering beneath a foundation, was done using a finite element analysis program. There are an infinite number of geometries and conditions for such a system and it is not practical to run the program for each combination of dimensions and properties. The goal, to provide a detailed summary of the expected results for any single group of conditions from the results of a few models, requires a range of variables covering normal values. Results cannot be specific to a few configurations of the system.

Dimensional analysis is a systematic grouping of variables into a dimensionless product. The product can represent a very small model of the system or a full size application. The trends and results predicted from a collation of the dimensionless numbers will be true for any combination of variables. From a dimensionless number the quantity of flow or free surface elevation between trenches can be evaluated for an infinite number of conditions.

In arriving at the dimensionless numbers for use in evaluation, the variables must be identified and cataloged by dimensions (Langhaar, Chap 3). The variables are then grouped into dimensionless products. The results of this

study of trench drain systems is presented in terms of dimensionless products. From inspection and experimentation the dimensionless numbers which provide the most insight are used in evaluating the models.

The variables in the study of dewatering a foundation by use of trench drains are listed:

- radius of influence (L), units of length
- hydraulic conductivity, horizontal (k_h), units of length/time
- hydraulic conductivity, vertical (k_v), units of length/time
- trench spacing, (S), units of length
- trench width, (d), units of length
- free head above trench bottom, (h), units of length
- aquifer thickness, (h+H), units of length
- number of trench drains, (N), no units
- slope of aquifer, (p), no unit

For this study only four trench drains were considered so no range of variables will be available from which to reasonably predict the characteristics of systems with other than four drains. The affect of other than four drains will not be considered. With a dimensionless product, later studies may determine a correlation between a four trench system and other configurations.

The aquifer slope will often be zero or near zero. A multiple of zero will reduce any dimensionless number to zero so the slope will also not be used in the dimensional analysis. Slope is a critical variable and the influence of aquifer slope will be shown by individual results and trends. For intermediate results interpolation between of the considered slopes will be necessary.

The width of drainage trenches considered for this study was restricted to one value. The trench width varies in practice and a value of 1.5 feet provides the minimum space necessary for placement of drainage pipe and granular backfill. If it is more necessary to make the trenches wider, the amount of dewatering will increase (Pirtle, Chap 4) and there will be less hydraulic rise in the water table between trenches. A wider trench is a more conservative approach and the variable for width of trench drains is included as a dimensional consideration.

Hydraulic conductivities, vertical and horizontal, are the only variables with other than a length dimension. This complicated the forming of dimensionless products. The vertical and horizontal conductivities had to be in the product, which left five variables, all with a single length dimension. There are five combinations to form a dimensionless product, each with six alternative

arrangements. This study was done with the vertical conductivity (k_v) equal to the horizontal conductivity (k_h) so the combinations for experimentation are:

$$\begin{array}{llll} L,d,S,h & L,d,S,(H+h) & L,d,h,(H+h) & (1) \\ & L,S,h,(H+h) & S,d,h,(H+h) & \end{array}$$

Each grouping has six different arrangements, yielding thirty possible dimensionless products. The results of the model runs were prepared in the dimensionless form. The products were compared and the arrangement which provided an insight into a relationship to total flow and the maximum free surface was selected for use. In this case the final product is:

$$Ld/h(h+H) \quad (2)$$

The variable not included in the product was the trench spacing. In Chapter 4 trench spacing is considered in evaluating the total flow and the maximum free surface between trenches.

III. Radius of Influence:

The distance over which the water level is lowered by dewatering is commonly referred to as the radius of influence. The radius of influence is the distance from the point or line of water removal to a point where the water table is not affected by the dewatering operation.

Obviously any model of dewatering or pumping operations is dependent on the radius of influence.

The radius of influence can be accurately determined in the field by a pumping test. A pumping test, using a fully penetrating well in an unbounded aquifer not in contact with a body of water, will provide a measured output and drawdown at known radii. The drawdown when plotted against the log of time will allow for the calculation of the effective conductivity of the soil. Under the Dupuit assumptions mathematical models ((a) Powers, pg 100) can project a drawdown for various distances and pump outputs. Calculation of the radius of influence is also available with this method. For a trench drain system the pumping test method has several problems. The trench drain is a method of open pumping or gravity flow and will have a significantly lower output than would a pumped well. By its nature the trench drain system is longitudinally aligned and would not be modeled by a well with accuracy. The trench drain does not fully penetrate the aquifer and will offer a different output than a fully penetrating well (Leonards, pg 270).

It is not unusual for the radius of influence to vary greatly, often differing by an order of three to four magnitudes ((a) Powers, pg 108). The radius of influence is affected by every variable of the system. In general the radius will increase with time and as the drawdown is

increasing. For pervious soils the radius of influence is greater than for a soil of less hydraulic conductivity (Leonards, pg 261). In the evaluation of a trench drain system, after construction of the foundation, the dewatering has reached a steady state condition. The effects of time and initial drawdown will not be considered in this study.

Normally the radius of influence is selected based on knowledge of the area and experience with design of dewatering systems. Several formulas exist to calculate the radius of influence, usually considering the hydraulic conductivity, thickness of aquifer, free head above point of lowest drawdown and adjustment factors. Several formulas are listed below:

Means of Calculating the Radius of Influence

1. $Q = (.73 + .27(H - h_0)/H) (kx/2L) (H^2 - h^2)$

Gravity flow to a partially penetrating slot (Leonards, pg. 271) with Q =total flow, H =aquifer thickness, h_0 =elevation of water in trench, x =length of trench, k = permeability and L =radius of influence. Use consistent units.

2. $L = 3.8h$

Highway subdrainage design (Moulton, pg 60) with h =drawdown in water level in feet, L =radius of influence in feet.

3. $R_o = 3hk^{1/2}$

Radius of influence as a function of drawdown ((a) Powers, pg. 109 after Sichart) with R_o =radius of influence, h =drawdown. Use consistent units.

4. $Q/x = K(H^2 - h^2)/L$

Water table flow from a line source to a drainage trench ((a) Powers, pg. 100). Q/x is the total flow per unit length of trench, k is permeability, H = thickness of aquifer, h = trench elevation, L = radius of influence. Use consistent units.

5. $G = S_y Lq / KH^2$

Predictive Analysis of Groundwater Inflows into Excavations (Freeze, pg. 494). G =a dimensionless discharge, S_y = specific yield, normally .01 to .3 (Freeze, pg. 61), K = hydraulic conductivity, H = aquifer thickness, q = rate of flow per unit length of trench, L = radius of influence. Use consistent units.

These formulas and others will predict a radius of influence for the characteristics of the problem. The prediction of a radius of influence for the foundation trench drain system is discussed in Chapter 4.

The radius of influence is an input value in the Aral Seepage Program. The program will calculate a quantity of flow and a water level free surface for a given radius of influence. The formulas from above and several others offer severe limitations to predicting the radius of influence. The formulas are not specifically for a trench drain system and to various degrees do not account for variations in horizontal and vertical permeability, partial penetration of the aquifer and gravity flow.

Water is produced from an unconfined aquifer by three mechanisms: (1) expansion of the water under reduced fluid pressures, (2) compaction of the aquifer under increased effective stress and (3) dewatering of the unconfined aquifer (Freeze, pg 324). In a gravity flow trench system water is not removed from the aquifer but, is carried away after it enters the trench (or leaves the aquifer). The water will leave the aquifer at a rate consistent with the Darcy principal, $Q = kiA$. Once steady state is attained the area, A becomes constant and so too is the flow. The amount of drawdown over the distance from trench to original water level (radius of influence) is the hydraulic gradient, i . The permeability is a property of the soil and is assumed to remain constant. The gradient in a steady state gravity flow system can only change with a rising (infiltration)

or lowering (depleted) water table. To change the gradient in a stationary water table an outside action must take place to change the fluid pressures or to physically remove water from the aquifer. Pumping would be a means of changing the gradient and hence the radius of influence and outflow of the system.

The theoretically correct radius of influence for ideal conditions was determined by running each trench drain configuration at a series of different radii. The resultant total flow of the system were plotted against the trial radii of influence. Total flow is the cumulative outflow from all four trenches. Figures 2-1 through 2-12 are the results of the runs. The above discussion shows the radius of influence to be at the distance where no further drawdown occurs. The trial radii greater than the true radius of influence yields a result at the true free surface. Lesser trial radii results in a forced solution with a larger gradient and higher flow. For this study the radius of influence was selected from the figures 2-1 through 2-12 as the distance where flow became constant.

Establishing the distance where total flow remained relatively constant required a uniform criterion to define unchanging flow. Arbitrarily, unchanging total flow was defined as 10% change over a 100 foot change in radius. This definition was selected after comparison of

the results across the thirty six different configurations of the problem as studied. For this problem, assuming a trench length of 200 feet the 10% change criterion is less than .05 gpm total flow.

The radius of influence is an extremely variable value, subject to interpretation and fine measurement. An accuracy of fifty feet was established as a reasonable estimation for the correct radius of influence.

Radius of Influence

(slope = 0%, $H = 20'$, $h = 10'$)

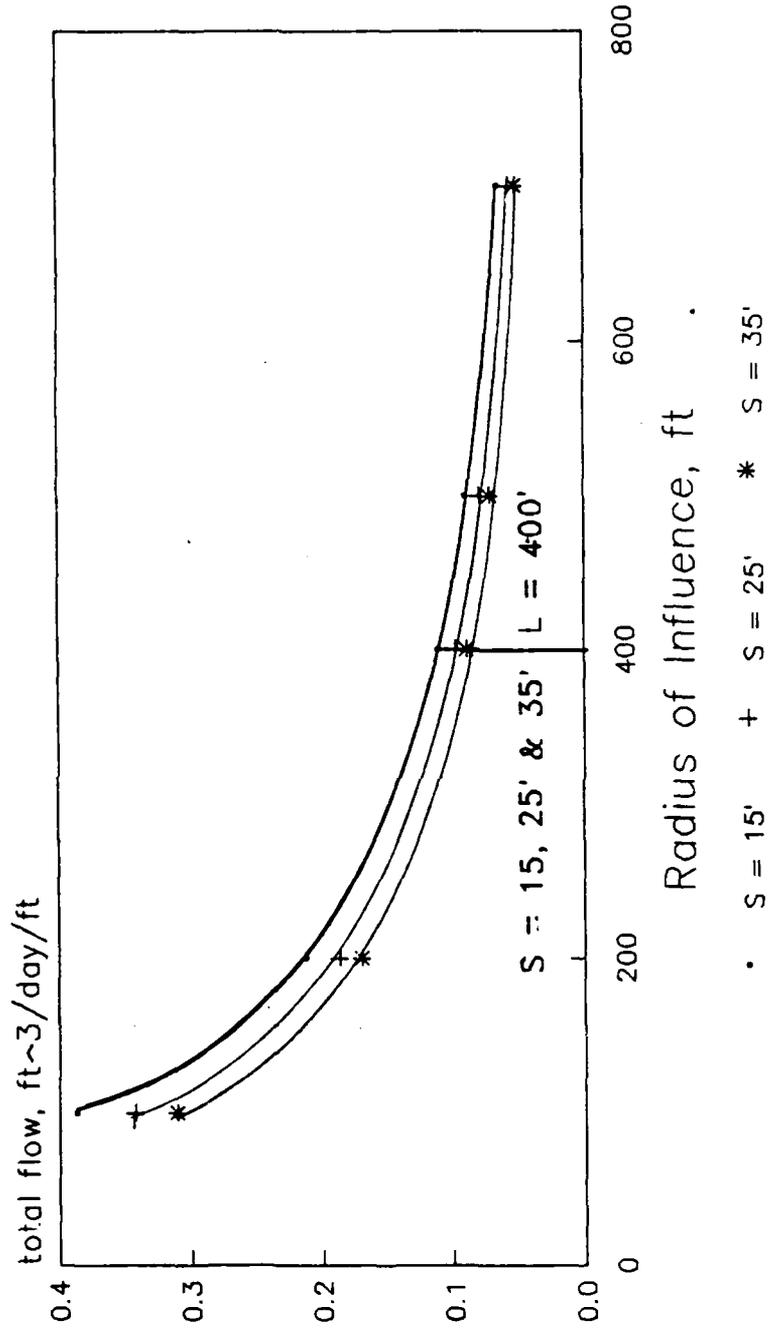


Fig. 2-1
 Determination of radius of influence
 S = Spacing, L = Radius of Influence

Radius of Influence

(slope = 0%, H = 20', h = 20')

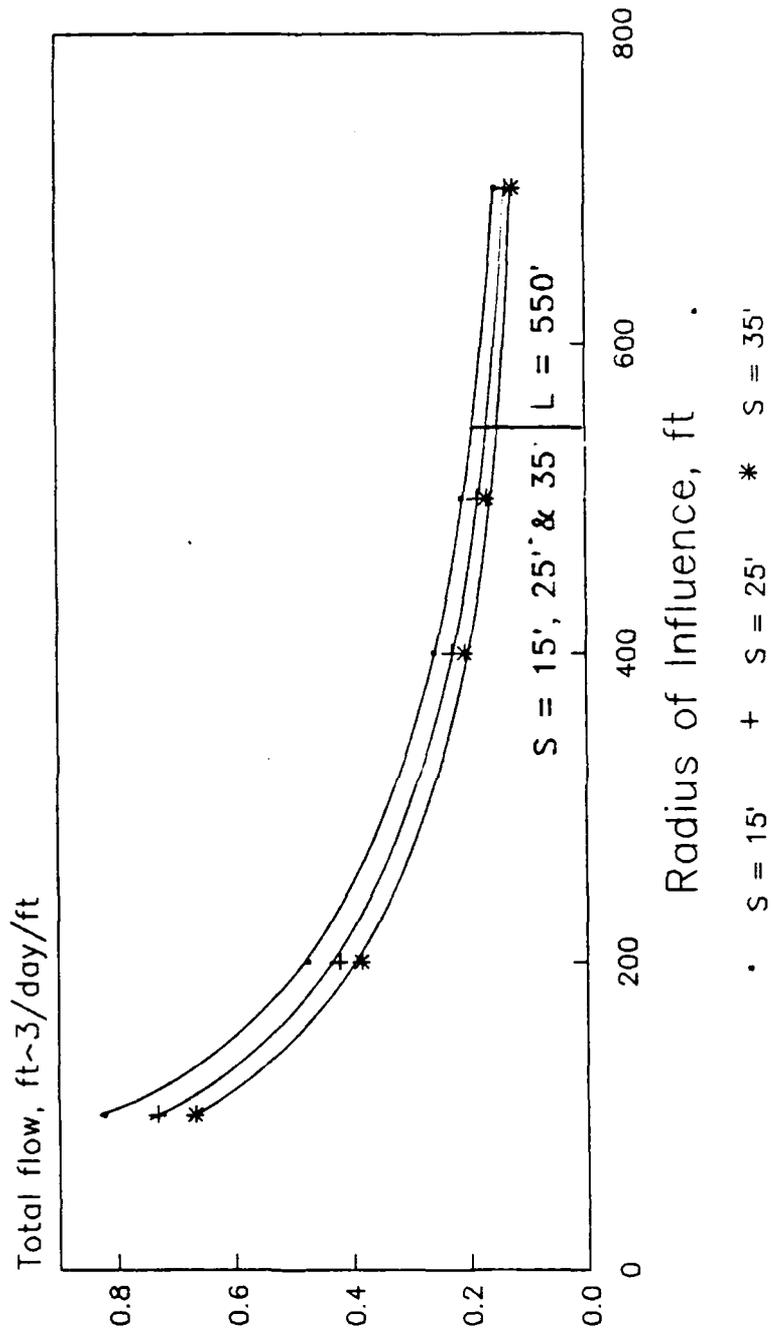


Fig. 2-2
 Determination of radius of influence
 S = Spacing, L = Radius of Influence

Radius of Influence

(Slope = 0%, H = 60', h = 10')

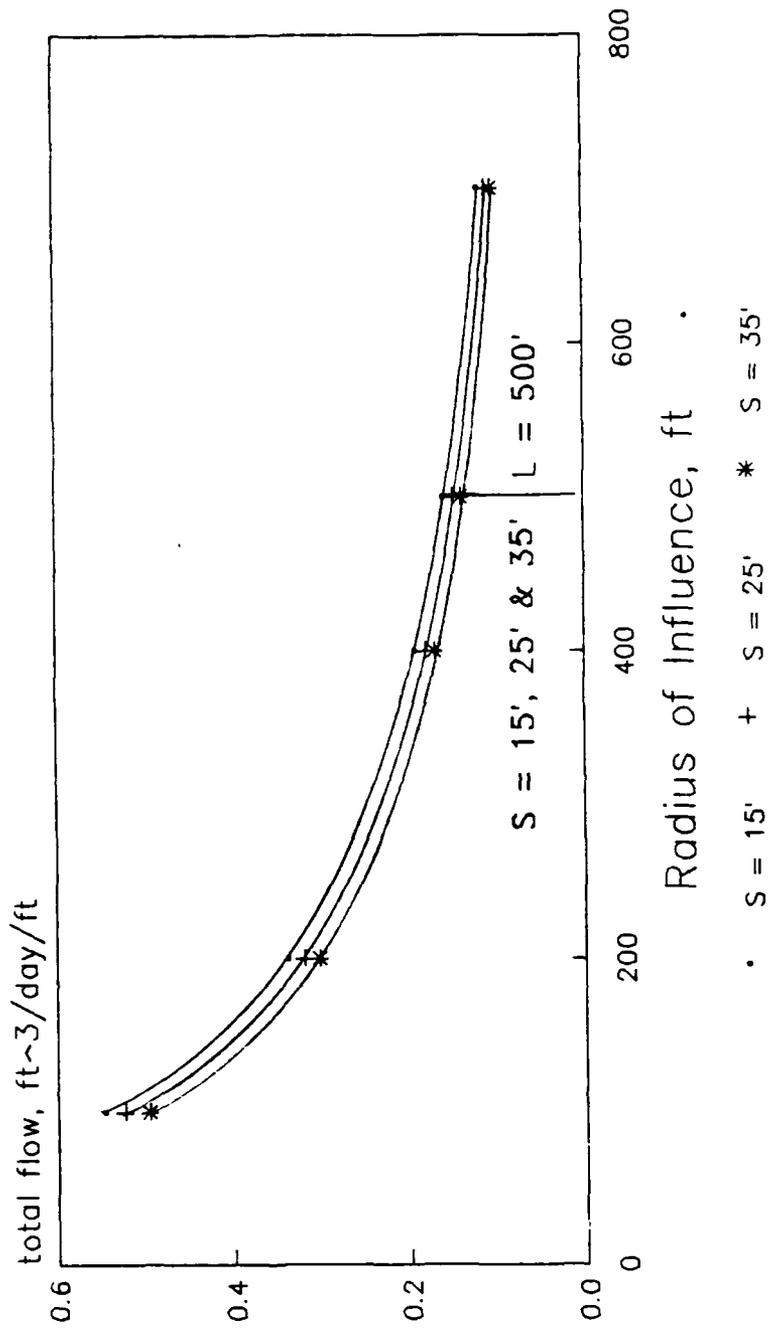


Fig. 2-3
 Determination of radius of influence
 S = Spacing, L = Radius of Influence

Radius of Influence

(Slope = 0%, H = 60', h = 20')

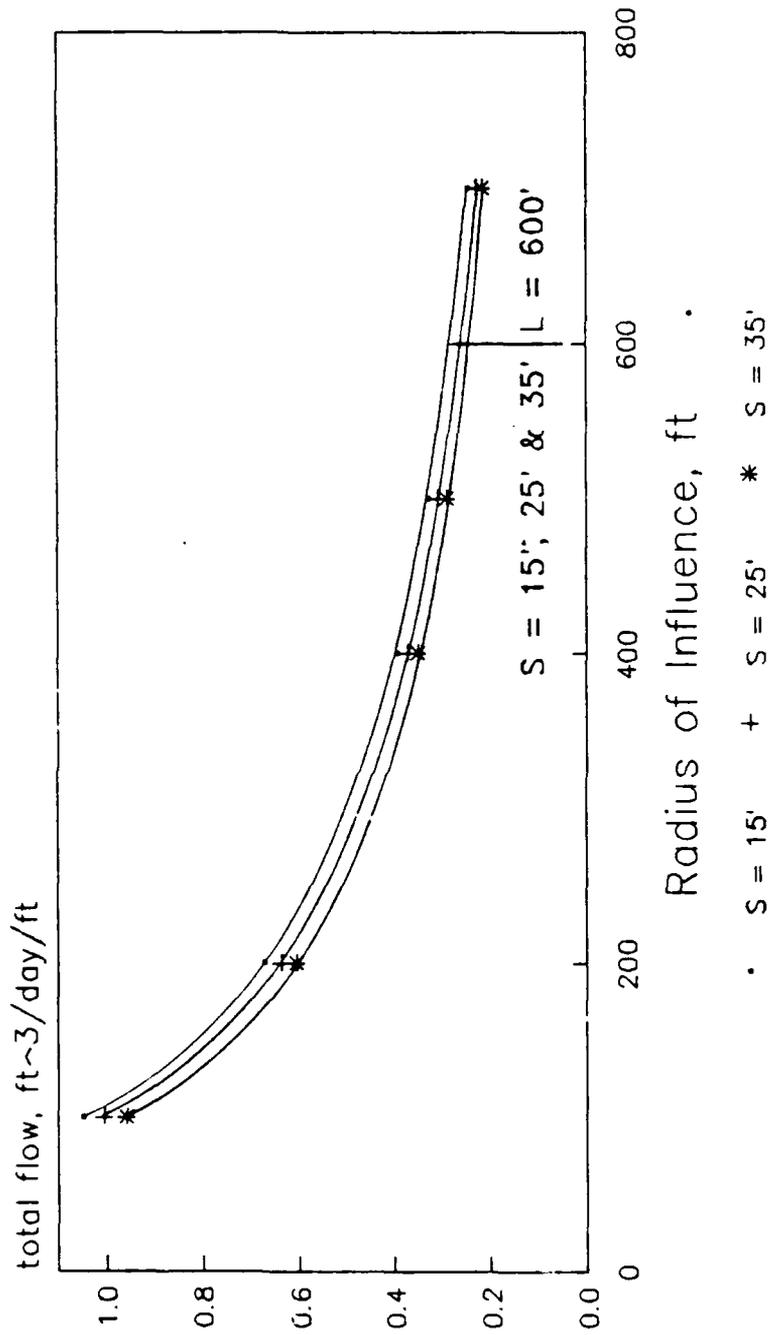


Fig. 2-4
 Determination of radius of influence
 S = Spacing, L = Radius of Influence

Radius of Influence

(Slope = 3.5%, H = 20', h = 10')

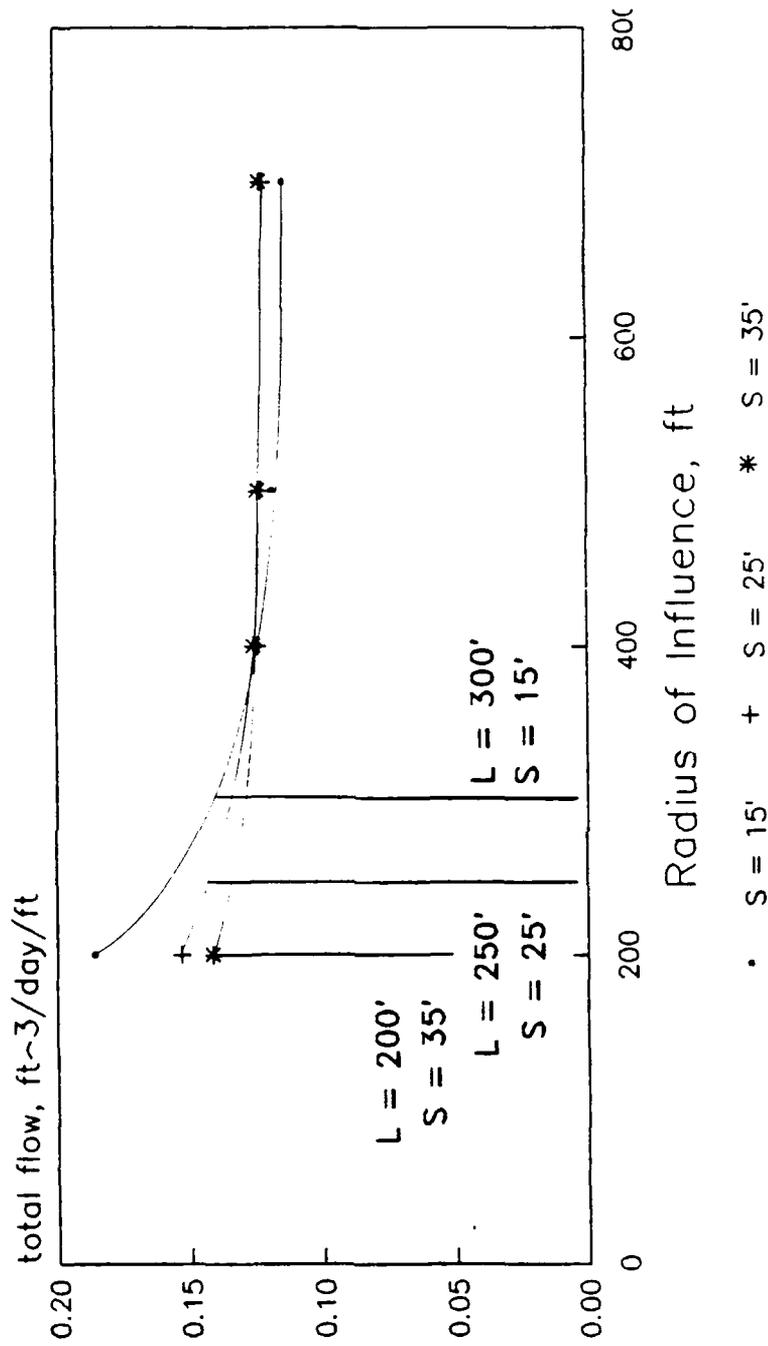


Fig. 2-5
Determination of radius of influence
S = Spacing, L = Radius of Influence

Radius of Influence

(Slope = 3.5%, H = 20', h = 20')

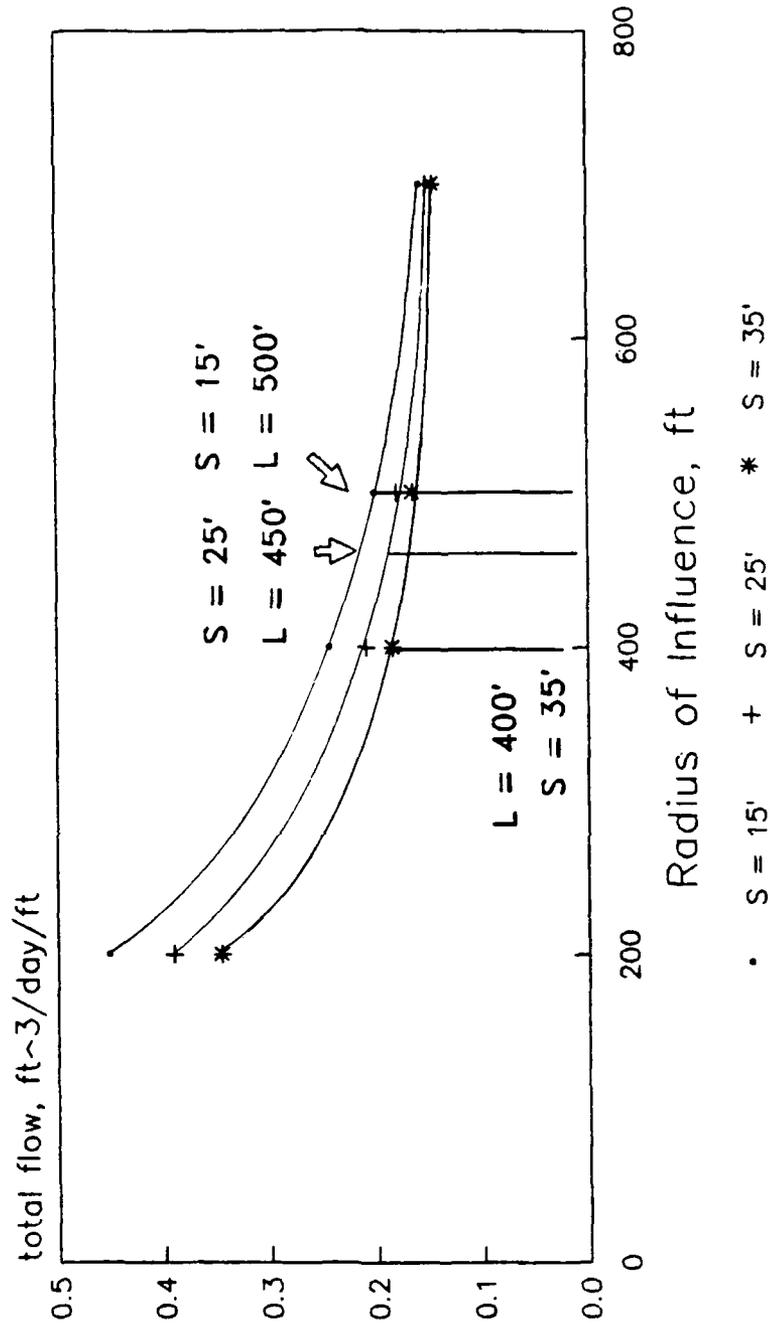


Fig. 2-6
 Determination of radius of influence
 S = Spacing, L = Radius of Influence

Radius of Influence

(Slope = 3.5%, H = 60', h = 10')

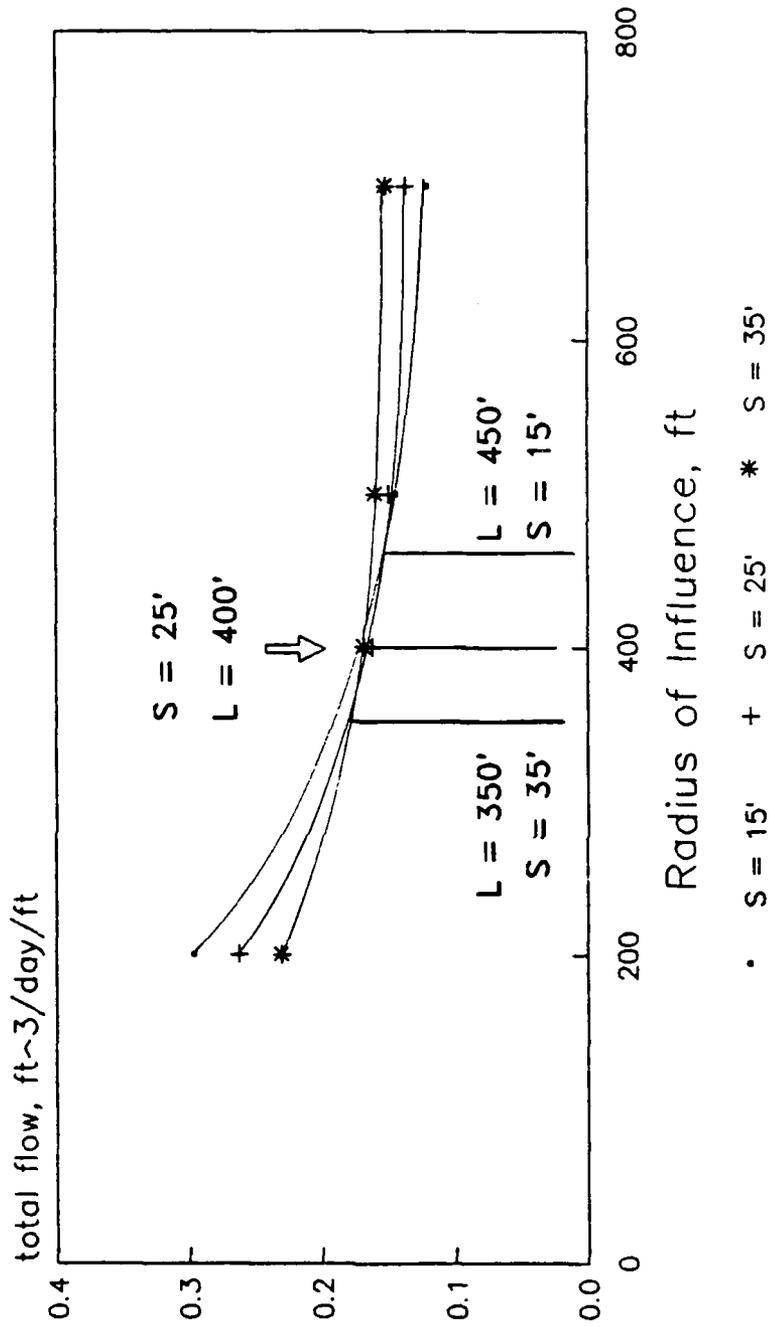


Fig. 2-7
 Determination of radius of influence
 S= Spacing, L= Radius of Influence

Radius of Influence

(Slope = 3.5%, H = 60', h = 20')

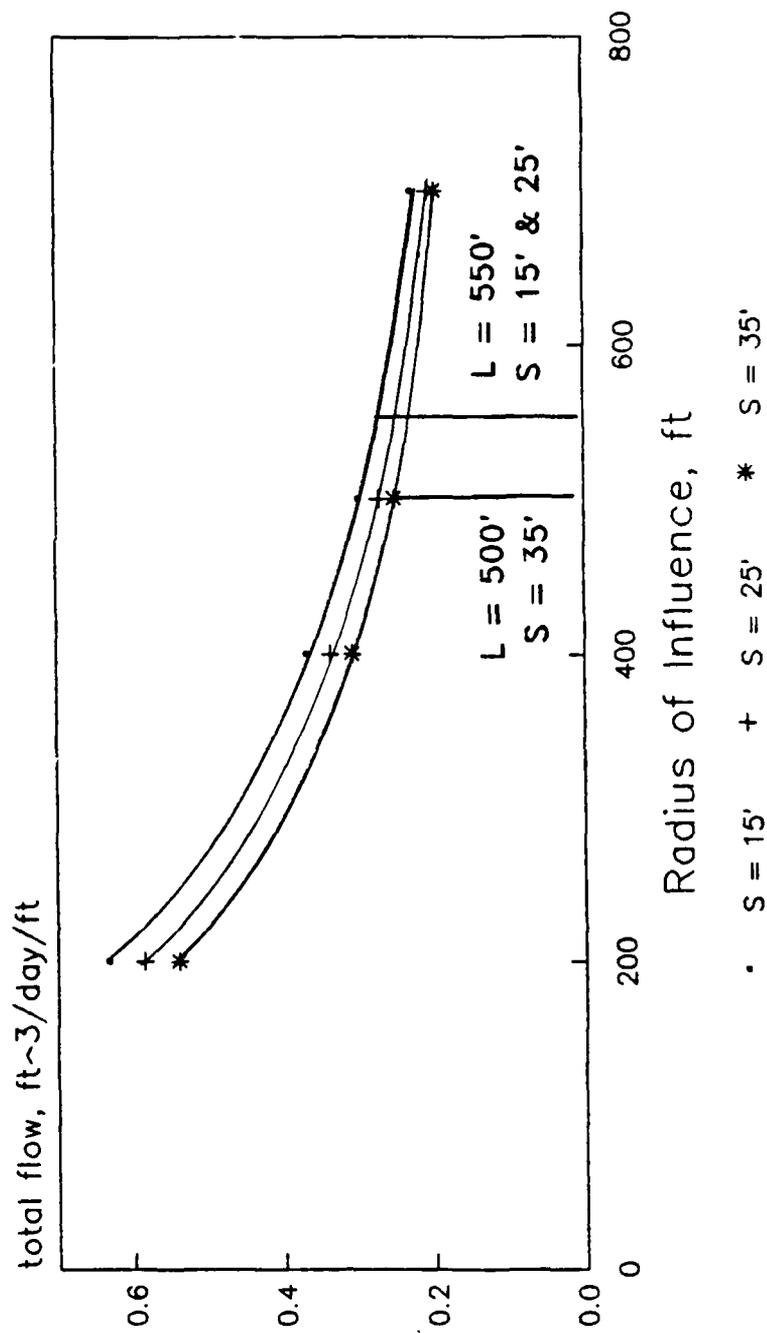


Fig. 2-8
 Determination of radius of influence
 S = Spacing, L = Radius of Influence

Radius of Influence

(Slope = 7%, H = 20', h = 10')

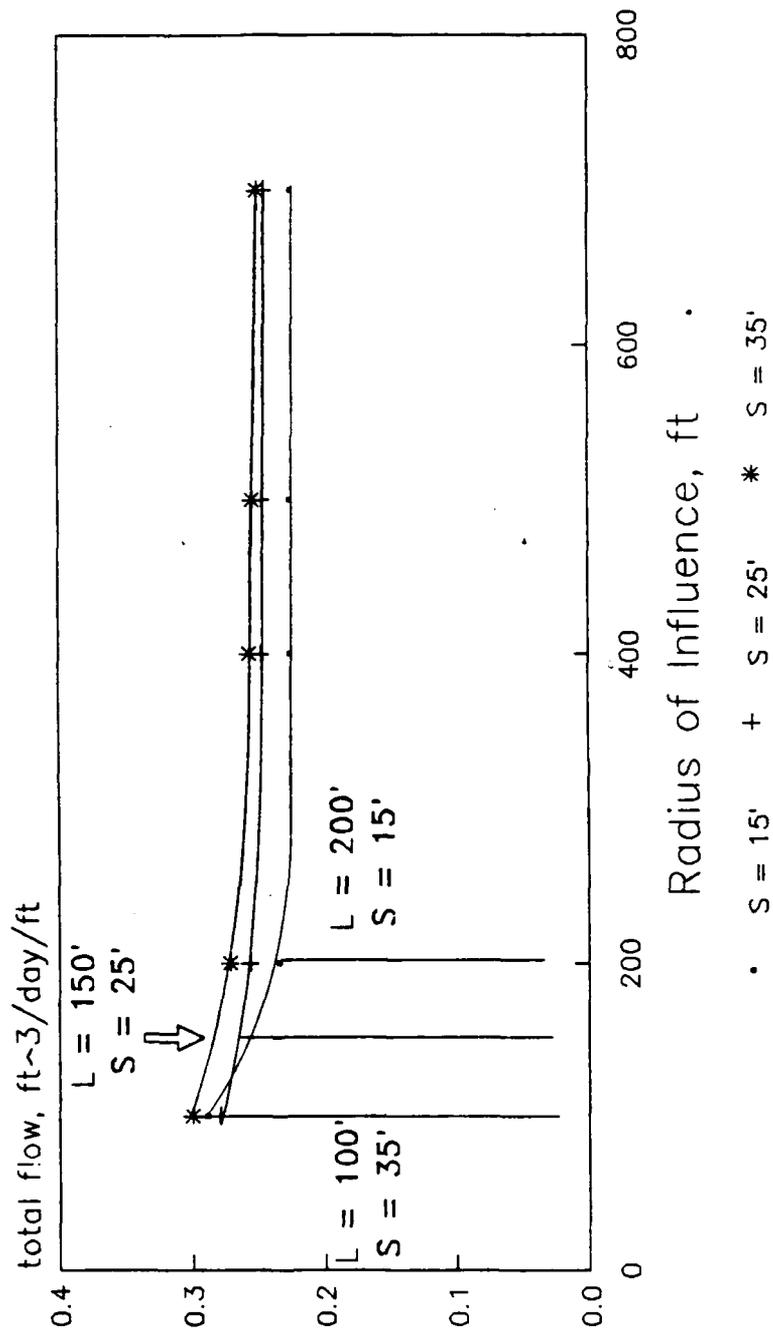


Fig. 2-9
 Determination of radius of influence
 S = Spacing, L = Radius of Influence

Radius of Influence

(Slope = 7%, H = 20', h = 20')

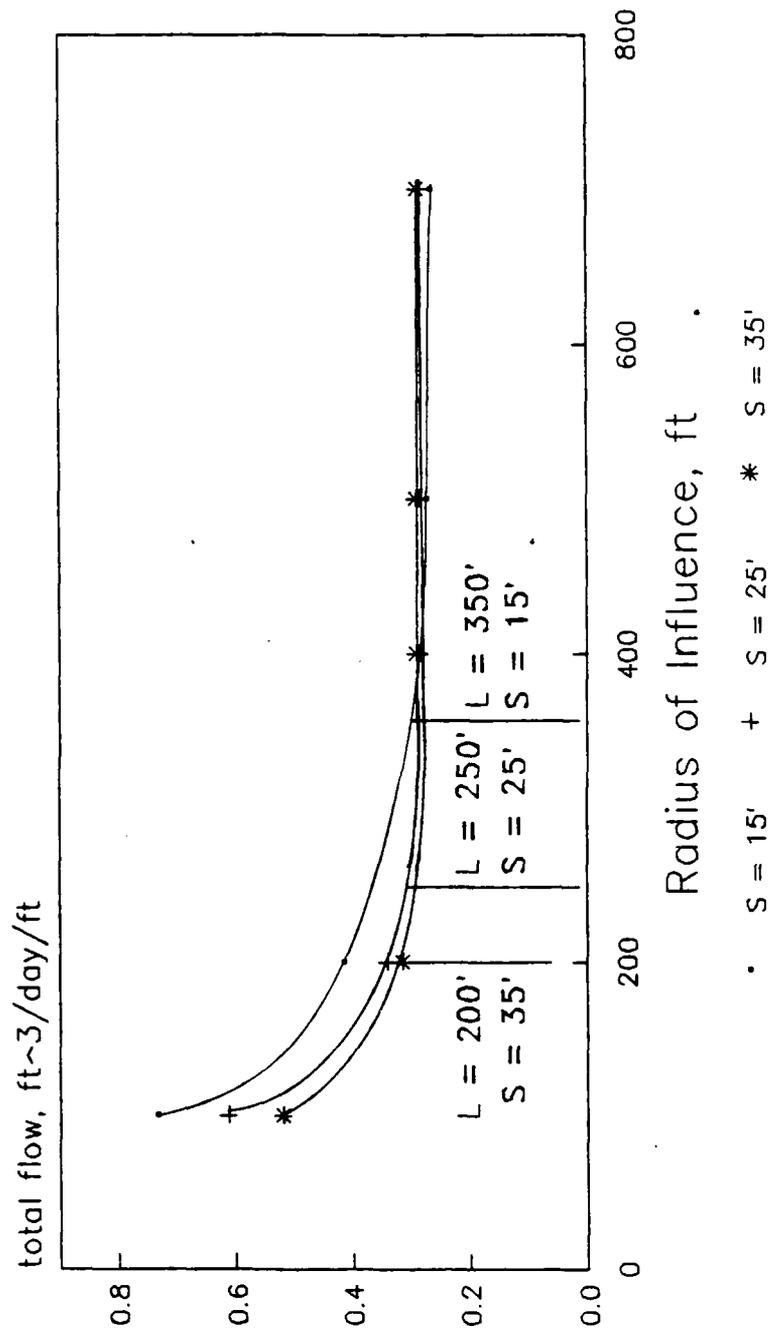


Fig. 2-10
 Determination of radius of influence
 S = Spacing, L = Radius of Influence

Radius of Influence

(Slope = 7%, H = 60', h = 10')

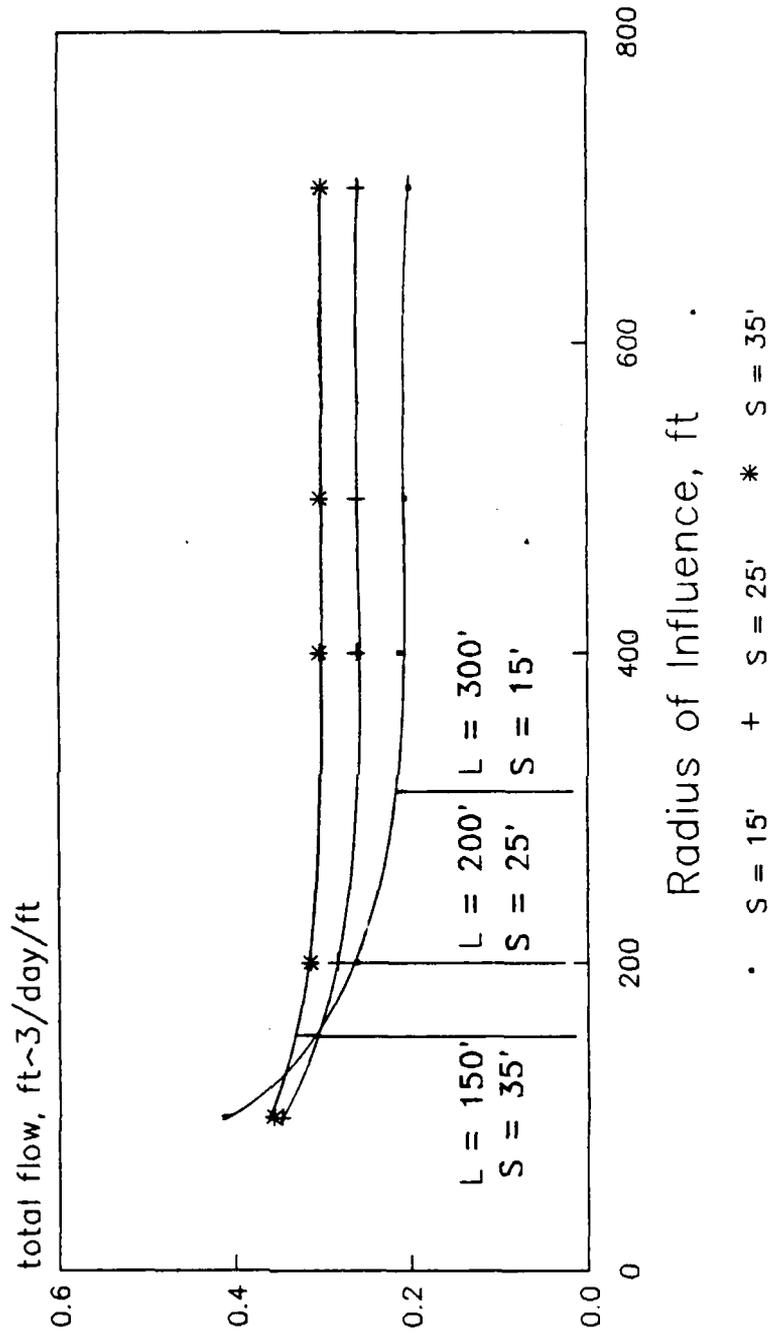


Fig. 2-11
 Determination of radius of influence
 S = Spacing, L = Radius of Influence

Radius of Influence

(Slope = 7%, H = 60', h = 20')

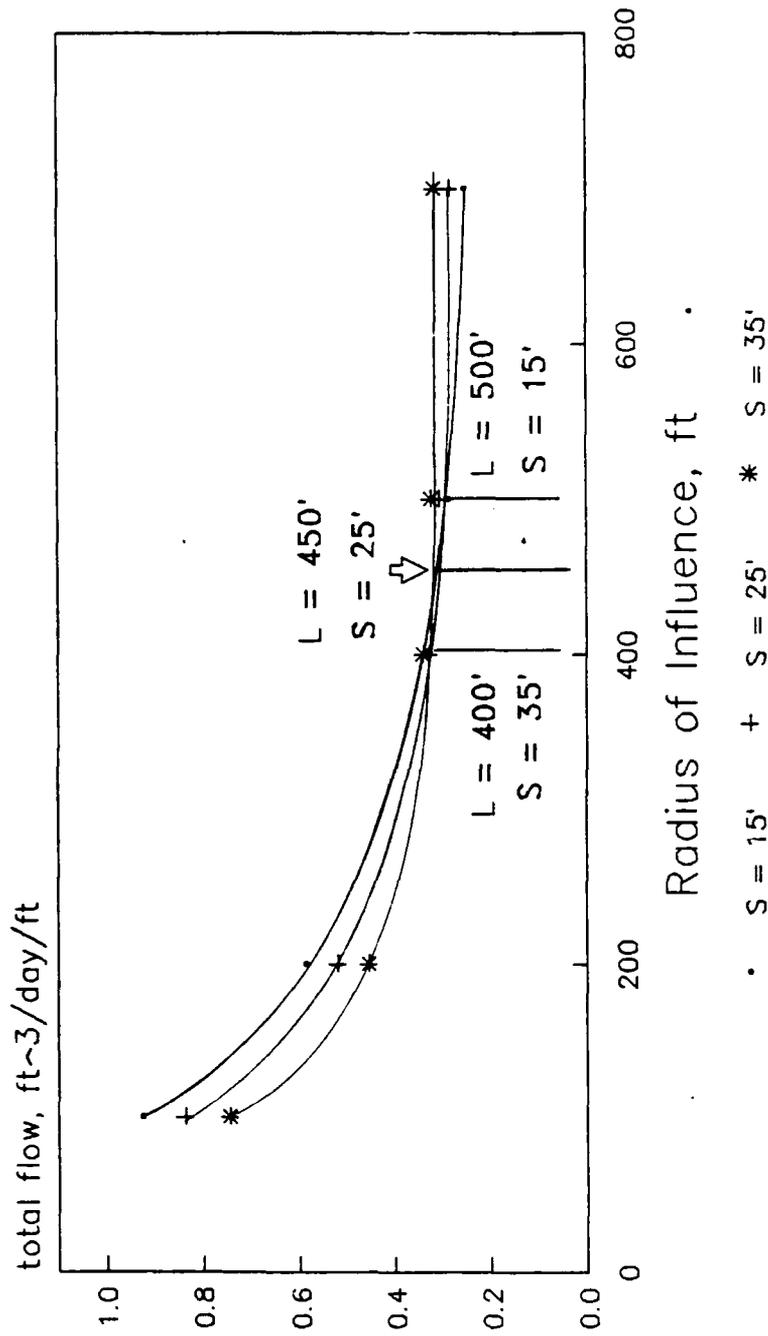


Fig. 2-12
 Determination of radius of influence
 S= Spacing, L= Radius of Influence

IV. Using Aral Seepage Program:

The Aral Seepage Program, a finite element model program was used in the evaluation of drainage characteristics of trench drain systems. An excellent program user's manual is included in an earlier study (Pirtle, Appendix A). Used for confined and unconfined flow problems of axisymmetric or two dimensional seepage, the program is available at Georgia Institute of Technology, Department of Civil Engineering.

The user inputs the problem geometry, soil characteristics and position of ground water. By equilibrium solutions to the discrete grid elements the program adjusts the initially assumed free surface through several iterations until the level of accuracy is satisfied. When completed a solution is presented to the defined problem, including total seepage flow through seepage faces and the steady state free water surface.

The referenced user's manual includes detailed sample input for an unconfined seepage problem. The evaluated trench drain system is of the same nature and so input was extremely similar. Appendix B of this study is a copy of an input data file for a run of the Aral Seepage Program for a trench drain. Figure 3-5 of Chapter 3 will provide node and element numbers as used.

Comments on the Aral Seepage Program User's Manual:

1. The user's manual does not provide guidance in setting the model sensitivity on the Title and Type Problem Card (card FERR). This card sets the degree of accuracy which will discontinue iterations of the free surface calculations. A precise number is not as important as maintaining a minimum number of iterations during the run. Recommended accuracy will be a value such that a minimum of three iterations are completed in the free surface calculations. The necessary value of sensitivity will become evident after several runs.

2. The control card input for NNPC, total number of corner nodal points, makes it clear that intermediate nodes will be generated between the listed corner nodes. What is not clear is that it is recommended that a line of elements several rows below the free water surface, should be defined as corner nodes. This establishment of an unmoving row close to the free surface reduces the iteration time. Iterations occur between the intermediate nodes and the free water surface. Figure 3-5 is a sample of the finite element mesh used in this study.

The Free Surface Nodal Cards include the top and bottom corner nodes of the "movable zone" described above. Sixteen corner nodes, or eight sets of free surface and base, are allowed for each card.

3. General program notes not included in the user's manual:

-The current version of the Aral Seepage Program is limited to thirty columns of elements.

-The total number of seepage faces with Dirichlet boundaries is not necessarily one less than the total number of Dirichlet Boundary faces. In the trench drain problem six boundary faces exist with only four drainage faces. In a problem done by symmetry there would be one less seepage face than the number of Dirichlet boundaries.

4. The output from the Aral Seepage Program is extremely straight forward with only one area of confusion. Appendix B of this study includes a copy of a printout result from the study. Under the "New coordinates of the Free Surface Line" there are several iterations of free surface corner nodal points and the x and y coordinates. The last iteration is the free surface calculated within the desired accuracy. A plot of the listed x and y coordinates is a cross section of the free water level. The maximum free surface elevation between trenches is the maximum value between any of the four trench drains. In Chapter 3 the selection of this value is reviewed. The last page of the output contains

the total seepage flow. The area of confusion comes from the presence of seepage output between trenches, across element faces not defined as seepage faces. Those output figures are not correct. Using the nodal address numbers from the bottom of the trench (Fig. 3-5) the actual seepage output at each trench can be obtained. To find the total flow the sum of trench flows is calculated manually as the listed total flow reflects the imaginary outflow between trench faces.

V. Evaluation:

In the analysis of the trench drain system dimensionless products will be used to prepare presentations of the affect of the many changing variables upon which the solution is dependent. The key variable is the radius of influence which will be determined by solving each model for several different radii and selecting the correct value by interpolation. Finally in the future use of the Aral Seepage Program several notes can be used to augment the existing user's manual.

CHAPTER 3

INPUT AND OUTPUT OF THE TRENCH DRAIN EVALUATION

I. Introduction:

The evaluation of different variables in a foundation trench drain involves a significant amount of input and output data. It is extremely important that methodical presentation and collection of data be practiced. This chapter details the system, under which all variables were considered. The approach used insured that the entire range under consideration was evaluated.

II. Problem Geometry:

In evaluating the dewatering trench drain systems the geometry must be established. Among the many variables in such an evaluation are the vertical and horizontal hydraulic conductivities of the soil, number of trenches in the system and width of the trench. To simplify the problem the above variables were held constant in this study.

Other variables in an evaluation are spacing between drains, thickness of the aquifer, free head above drains and slope of the aquifer. These factors were varied in this study over ranges sufficient to determine the characteristics of the system under as normally used.

Confined flow was not considered in this study and each case was for a water table aquifer. A confined aquifer cannot be dewatered effectively with an open pumping or sump method

((a) Powers, pg 114). A significant assumption of phreatic flow, included in the finite element analysis, provides the radius of influence of drawdown.

A primary concern in dewatering a water table aquifer is the storage depletion ((c) Powers, pg.3). This study concerns trench drains under steady state conditions following construction. In steady state, the storage has been depleted and will not contribute additional flow.

The previous study (Pirtle) was conducted under symmetry as a half space problem with no slope. The finite element method in a half space works very well until a sloping aquifer is considered. Use of symmetry permits evaluating one half of the problem, doubling the results accurately models the full problem. To do this with a sloping aquifer models a perched water table. Figures 3-1 and 3-2 represents one half of a system under symmetry and a full system respectively.

For this study the affects of a sloping aquifer were essential, and a full width model was required. Figure 3-3 is a representation of the cross section of the sloping aquifer. In the full width model the free water surface both upstream and downstream of the foundation trench drain must be evaluated. Figure 3-4 is a cross section of the problem with the assigned variable names.

In the model four trench drains were selected. Although this models a relatively small foundation it should yield results which may be used conservatively for larger

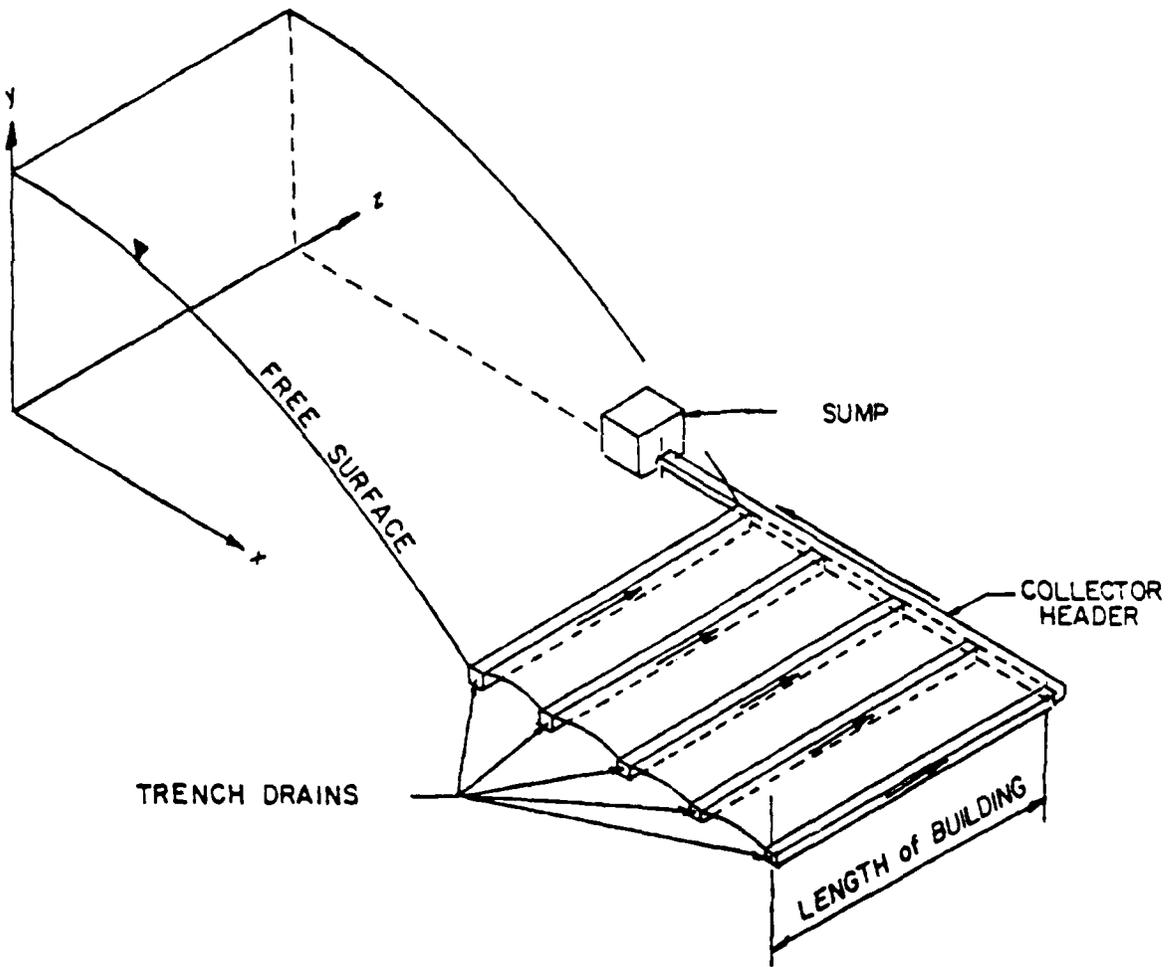


Fig. 3-1 Underdrain System in Half Space
(after Pirtle)

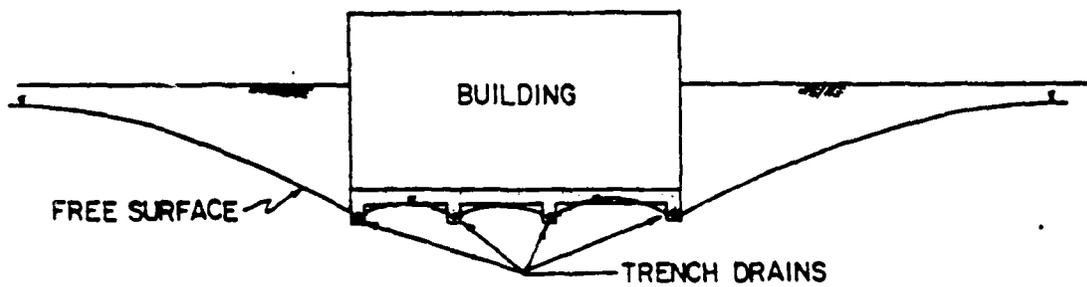


Fig. 3-2 Typical application of Trench Drain
(after Pirtle)

TRENCH DRAIN SYSTEM

Profile

($L_t = 200'$, slope 3.5 %)

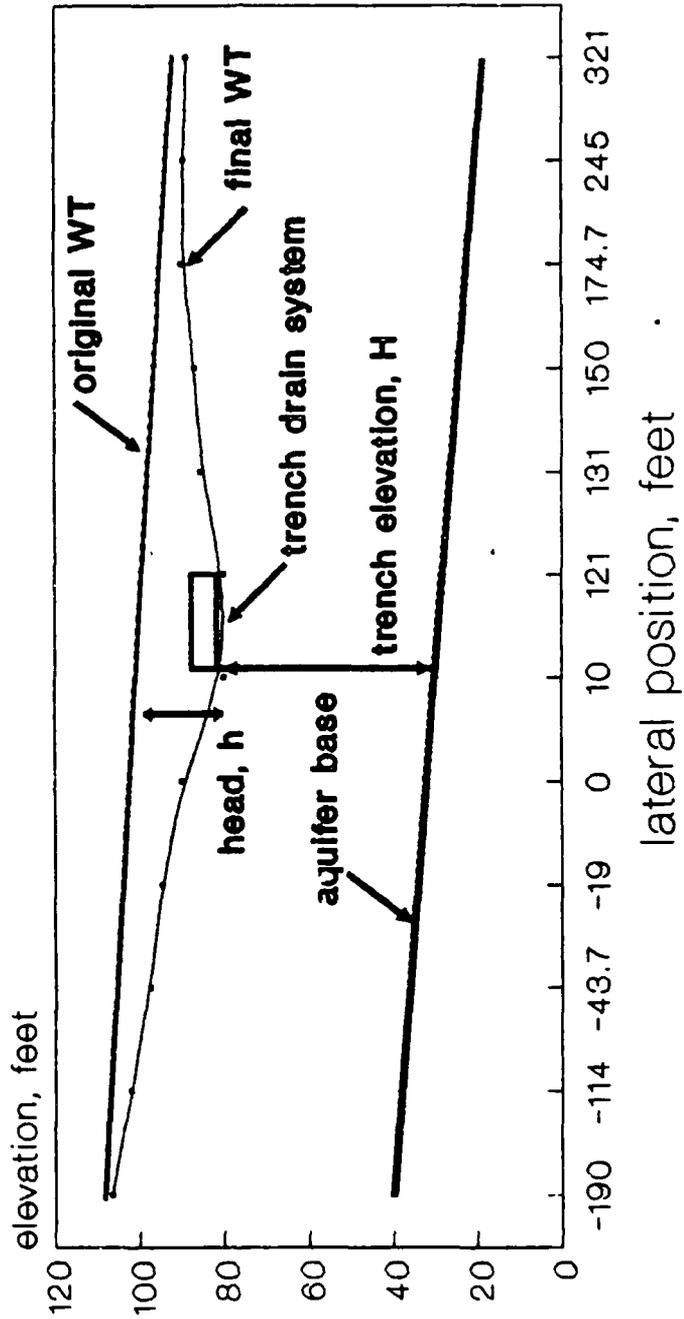


Fig. 3-3
Typical cross section of trench drain
system with original aquifer boundaries

CROSS SECTION

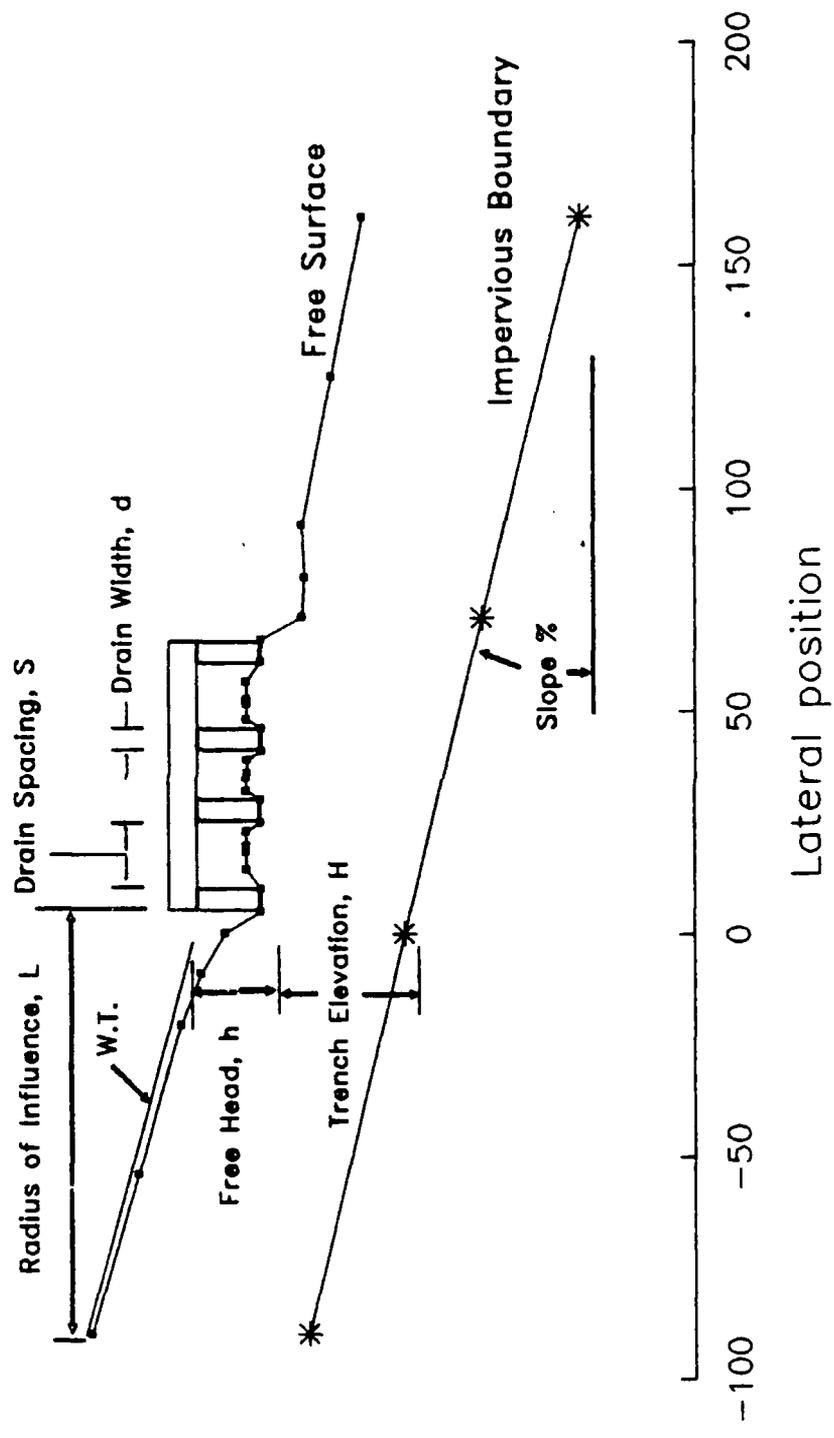


Fig. 3-4
Variables of Trench Drain Analysis

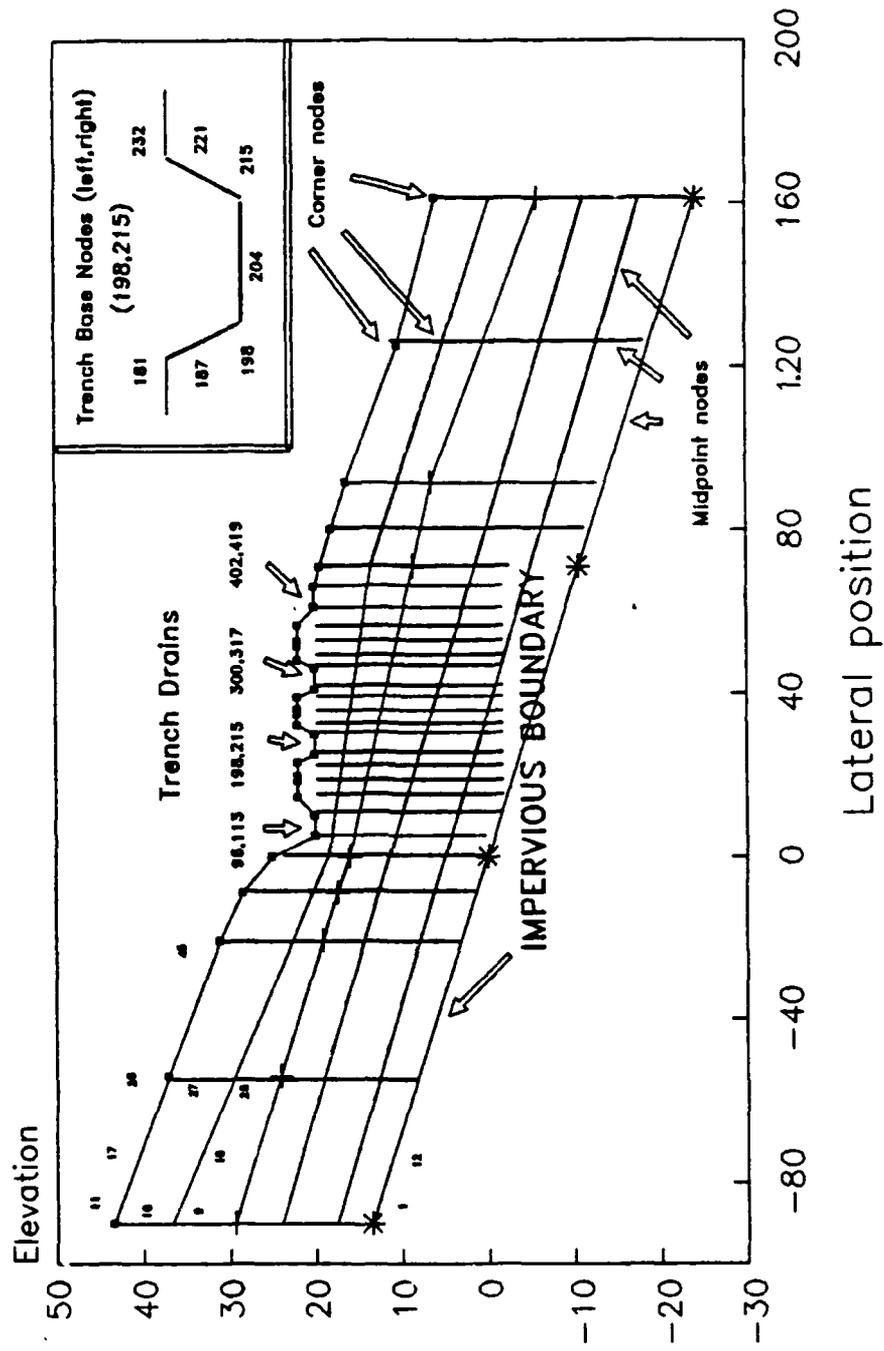


Fig. 3-5
Example Mesh Used

foundations. Generally in a sloping aquifer the majority of dewatering and the maximum free surface between trenches occur due to the outboard drain. For a sloping aquifer this model will closely model even a large foundation as most of the removed water is into the upstream trench. The number of drains might be a prime area for future study.

The width of the drainage trenches were held at one and one half feet wide. While the earlier study (Pirtle, Chap 4) showed total flow to vary with drain width, it is reasonable to select a single, typical value. The use of 1.5 feet is based on the approximate width of a normal backhoe bucket.

The horizontal hydraulic conductivity (permeability, k_h) was selected as a constant $0.2 \text{ ft}^2/\text{day}/\text{ft}$ which is, $7 \times 10^{-5} \text{ cm}/\text{sec}$. This is the normal permeability of a silty sand ((b)Cedergren, pg 34), common to the Atlanta area.

For the vertical hydraulic conductivity (K_v) the same $0.2 \text{ ft}^2/\text{day}/\text{ft}$ was used. While a reasonable value, it does not reflect the normal condition of a greater horizontal hydraulic conductivity, which may be greater than the vertical by a multiple of three to ten times ((a)Powers, pg.92). It would be an excellent study to evaluate the affects of anisotropy in the trench drain system.

The primary area of concern in this study were the affects of a sloping aquifer. To consider a complete range, three slopes considered. Initially 0%, 7% and 15% slopes were selected. The aquifer thickness remains the same through the

area of consideration with a uniform aquifer base and water table slope. Once the study was begun it became apparent that the 15% slope was too severe. The study was modified with 7% the maximum slope considered and additional data was collected for a 3.5% slope.

Trench drain spacing was evaluated using 15 feet, 25 feet and 35 feet. For the assumed four drain system this allows consideration of a foundation from 60 to 120 feet wide. In actual practice the trench drains are excavated between the column lines so normal spacing is that of the column spacing. The results for a model with trench spacing of 25 and 35 feet are most likely to be used.

An assumption for this study was that the aquifer remain of constant thickness across the entire area of water table depression. For some models this area is 1000 feet across. It is certainly not a normal soil condition for the aquifer to be so uniform. In general the area of depression is significantly smaller than the above value. Assuming uniform thickness for distances of 300 and 400 feet is reasonable.

To separate the affects of free head from thickness of aquifer the later was considered as two components. The first component was thickness below the drain or trench elevation (H) and the second was free head above drain (h). The sum of the two components is the total aquifer thickness.

To bracket normal conditions in the evaluation of trench drains a maximum aquifer thickness of 80 feet was used. While

arbitrary this value is reasonable in an aquifer at the surface. The minimum aquifer thickness used was 30 feet. Certainly smaller aquifers exist at the ground surface but, a trench drain would probably not be as effective as a cutoff wall in protecting the foundation for such a shallow depth.

The last variable considered in the study was the free head of aquifer above the bottom of the trench drain. As described above the free head is a component of the aquifer thickness. Free head was held at a maximum of 20 feet. As the free head increases the amount of water removed must also increase. Under an open draining trench system the radius of influence is much larger and interference with other structures is a problem. As a free head of 20 feet is approached alternative dewatering methods may have to be considered.

The minimum free head considered was ten feet. This value was selected arbitrarily. The foundation trench system would work very well for a smaller free head. In retrospect the minimum head considered should have been five feet. Less free head and the necessary trench depth would be so small that a blanket drain would be more economical. A comparison of the two drain systems will be undertaken on an economics basis in Chapter 4.

III. Naming and numbering convention:

As a shorthand means of identifying the variables (Figure 3-4) of this study each is named as follows:

Radius of influence, L

Total flow, q

Aquifer slope, p

Trench spacing, S

Trench elevation, H

Free head above trench, h

Maximum free surface height, F

Hydraulic conductivity (vertical), k_v

Hydraulic conductivity (horizontal), k_h

As described in Chapter 2 the determination of an accurate radius of influence involved four to six trial runs of a model. The result was 36 geometries and over 200 computer runs. In order to identify the geometry of each trial the data files and resultants were named from a file convention. An alpha-numeric name of six characters, with

each one have several values was used. The files were named and the data sorted as follows:

A12345.dat, where the .dat is a conventional suffix of the operating system

First Character (A)

Vertical hydraulic conductivity, k_v

$$A = 0.2 \text{ ft}^2/\text{day}/\text{ft}$$

Second Character (1)

Aquifer slope, g

$$0 = 0 \%$$

$$3 = 3.5 \%$$

$$7 = 7 \%$$

$$9 = 15 \%$$

Third Character (2)

Radius of influence, L

$$3 = 100 \text{ ft}$$

$$5 = 200 \text{ ft}$$

$$8 = 400 \text{ ft}$$

$$9 = 500 \text{ ft}$$

$$0 = 700 \text{ ft}$$

Fourth Character (3)

Trench spacing, S

$$3 = 15 \text{ ft}$$

$$5 = 25 \text{ ft}$$

$$7 = 35 \text{ ft}$$

Fifth Character (4)

Trench elevation, H

2 = 20 ft

6 = 60 ft

Sixth Character (5)

Free head, h

1 = 10 ft

2 = 20 ft

The above convention is used in this study in names of data files. If a collection of data is gathered so that each group has a constant trench elevation, H and free head, h the data groups will be referenced by AxxxHh. In this example if the H = 20 feet and h = 10 feet the data group will be Axxx21. The data files used in this study are included in Appendix D.

IV. Conduct of study:

The primary output of the finite element analysis used in this study were the total drainage outfall per lineal foot of trench drain system and the maximum free surface of groundwater between trench drains. As detailed in Chapter 2 the study first had to determine the radius of influence for each condition. From Figure 3-5 the elements of the finite element grid between can be observed. The width between trenches was divided into five spans. So at four nodes the iterative determination of the FEA program predicted an

ultimate final elevation. This was determined for every trial radius, L and the maximum node elevation observed was recorded. Figures 3-6 through 3-9 are profiles, in the trench area, of the represented free surface for several trial runs.

It was expected that the maximum free surface (F) would occur near the center of the trench spacing (S). In order to obtain an accurate maximum free surface, the nodes between drains were not evenly spaced. Instead, the distance between nodes were greater near the trenches. For each run the maximum free surface selected was that of the maximum nodal elevation. This is obviously not accurate in all cases. An interpreted maximum free surface (F) would increase many of the values used but, would not reduce any value. The anticipated difference in magnitude of maximum free surface (F) does not exceed 0.01 feet or 0.1 inch. This potential error is not significant.

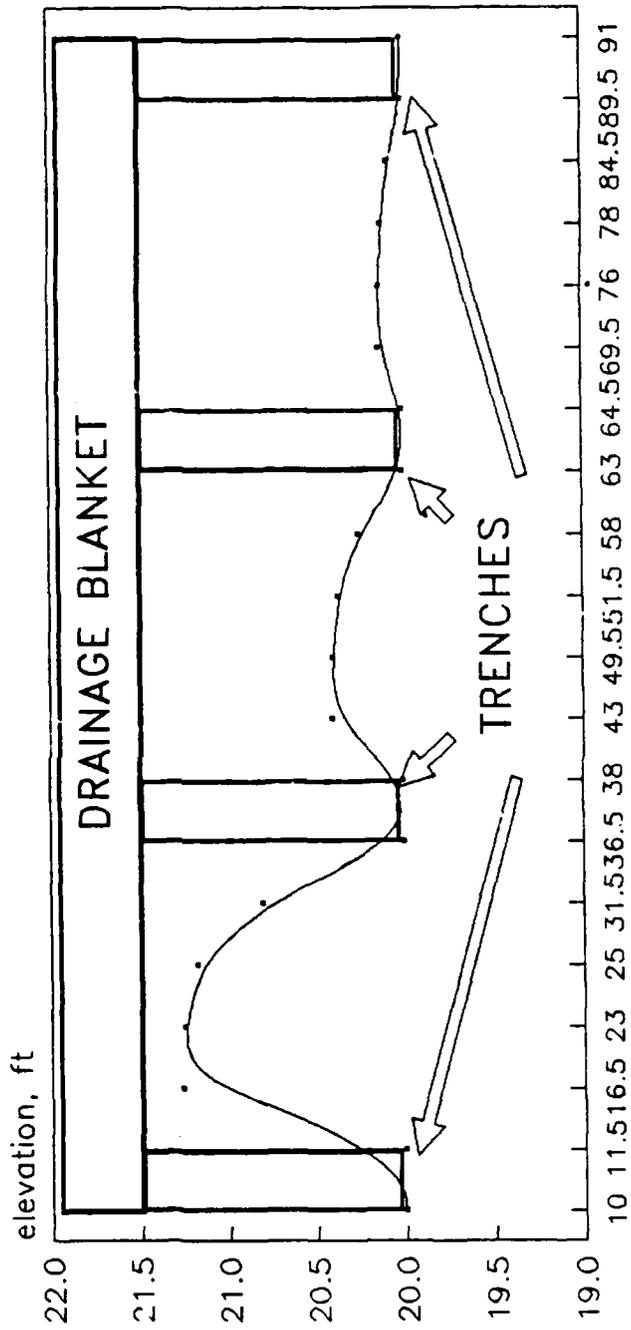
A review of the maximum free surface value for the many different finite element analysis runs revealed that the maximum free surface (F) always occurred between the outer most trench and the second trench. In an aquifer with no slope the conditions surrounding the outer trench were the same for both sides. On a sloping aquifer the maximum free surface (F) was at the upstream side of the trench drain system.

With the maximum free surface available for every geometry of problem and every trial radius of influence there

FREE SURFACE PROFILE

Slope = 7%, L = 200', Spacing = 25'

H = 20', h = 20'



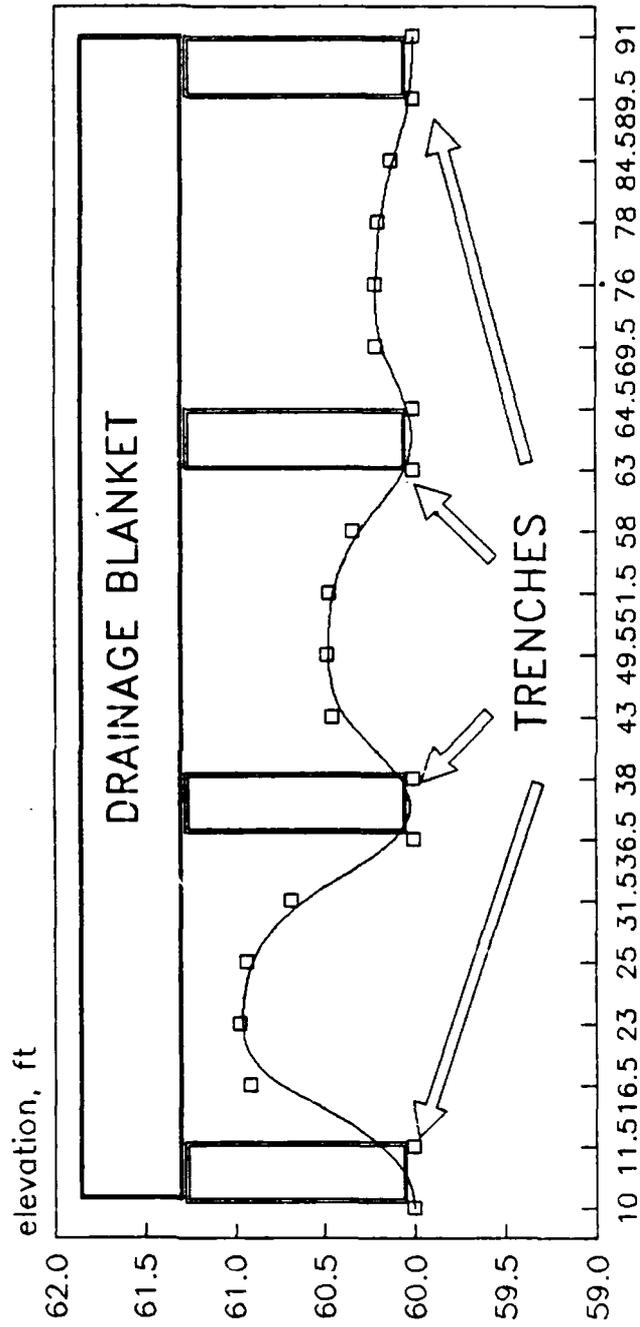
lateral position within trench area

Fig. 3-6
Free surface between trenches

FREE SURFACE PROFILE

Slope = 3.5%, L = 700', Spacing = 25'

H = 60', h = 20'



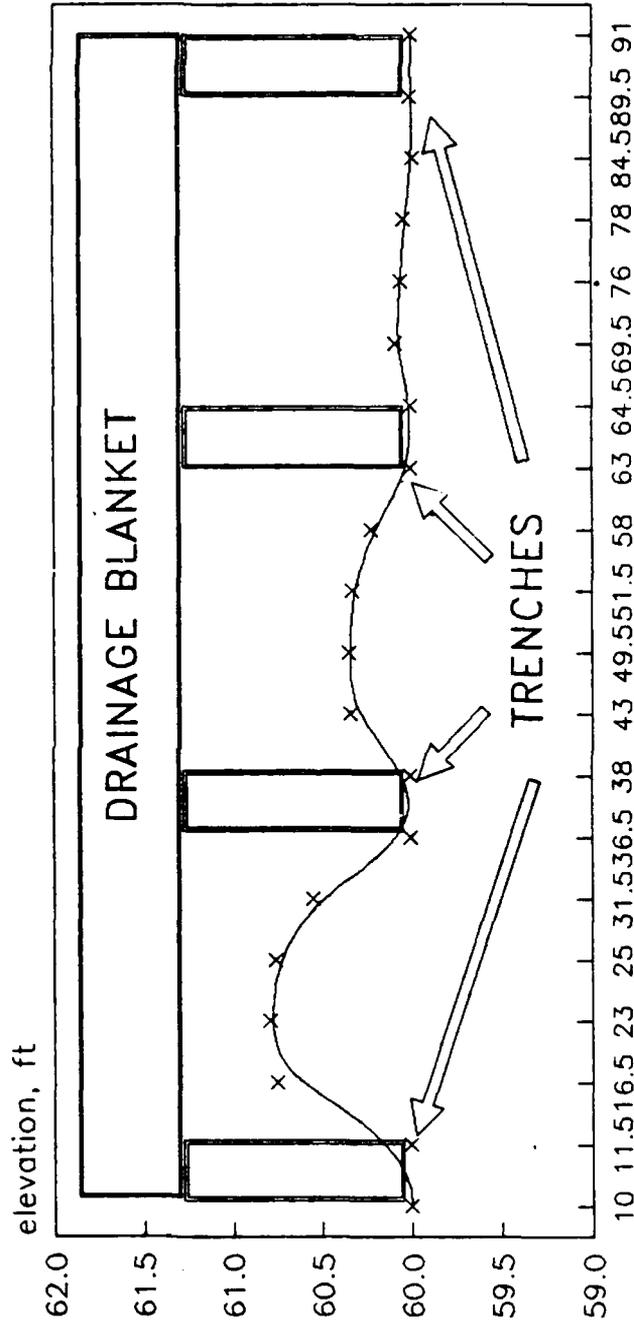
lateral position within trench area

Fig. 3-7
Free surface between trenches

FREE SURFACE PROFILE

Slope = 3.5%, L = 400', Spacing = 25'

H = 60', h = 10'



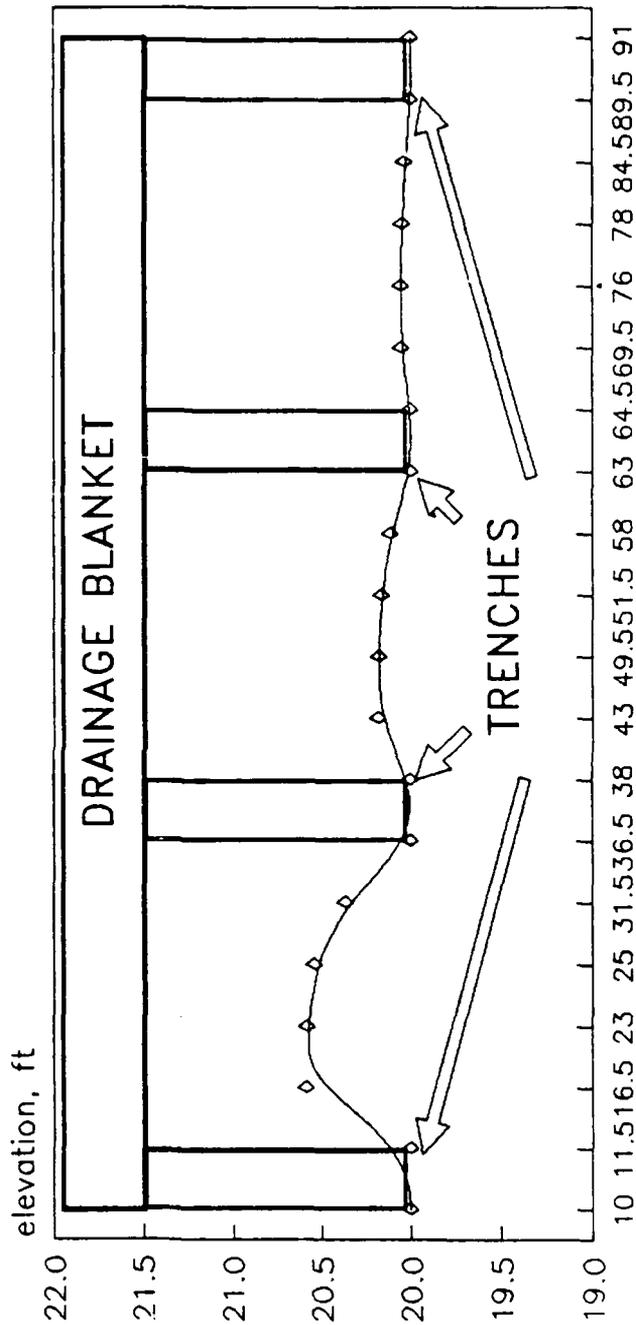
lateral position within trench area

Fig. 3-8
Free surface between trenches

FREE SURFACE PROFILE

Slope = 3.5%, L = 200', Spacing = 25'

H = 20', h = 20'



lateral position within trench area

Fig. 3-9
Free surface between trenches

remained the evaluation of the maximum free surface (F) at the theoretically correct radius of influence. Fortunately from Figures 3-10 through 3-21 it is obvious that the maximum free surface varies with trial radius of influence in a consistent manner. As the theoretically correct radius of influence (L) is known from Chapter 2, the maximum free surface can be scaled from Figures 3-10 through 3-21. By convention the interpolation of data to evaluate the radius of influence used only values which were multiples of 50 feet.

The definition of a theoretically correct radius of influence at the distance of unchanging total flow defines the radius from the known phraetic nature of the problem. The unchanging flow also quantifies the total flow expected from the system. For this problem total flow was done per unit of width, making this a two dimensional problem.

The total flow, the maximum free surface and the radius of influence for each geometry of problem are now available. Analysis of trench drain systems were done with this data.

MAXIMUM FREE SURFACE

(Slope 0%, $H = 20'$, $h = 10'$)

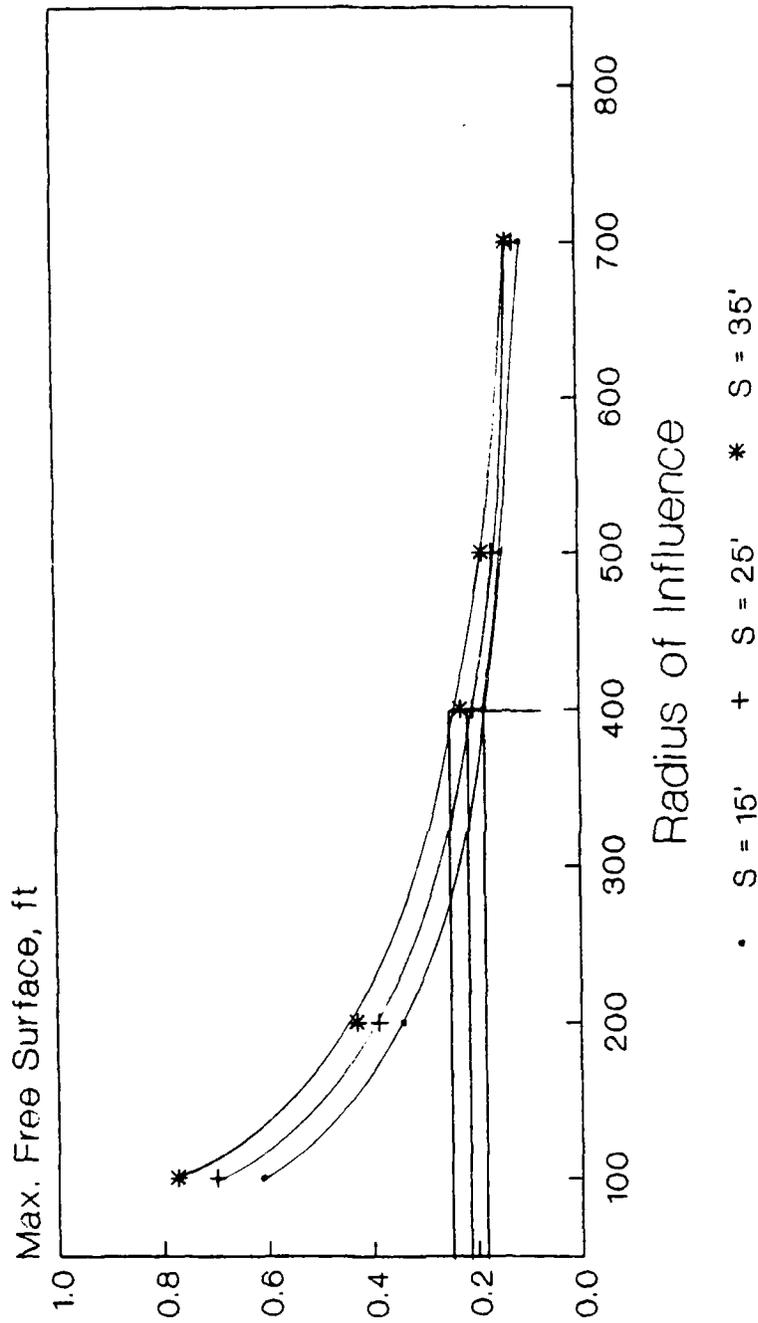


Fig. 3-10
Finding the Max. Free Surface
between trenches

MAXIMUM FREE SURFACE

(Slope 0%, $H = 20'$, $h = 20'$)

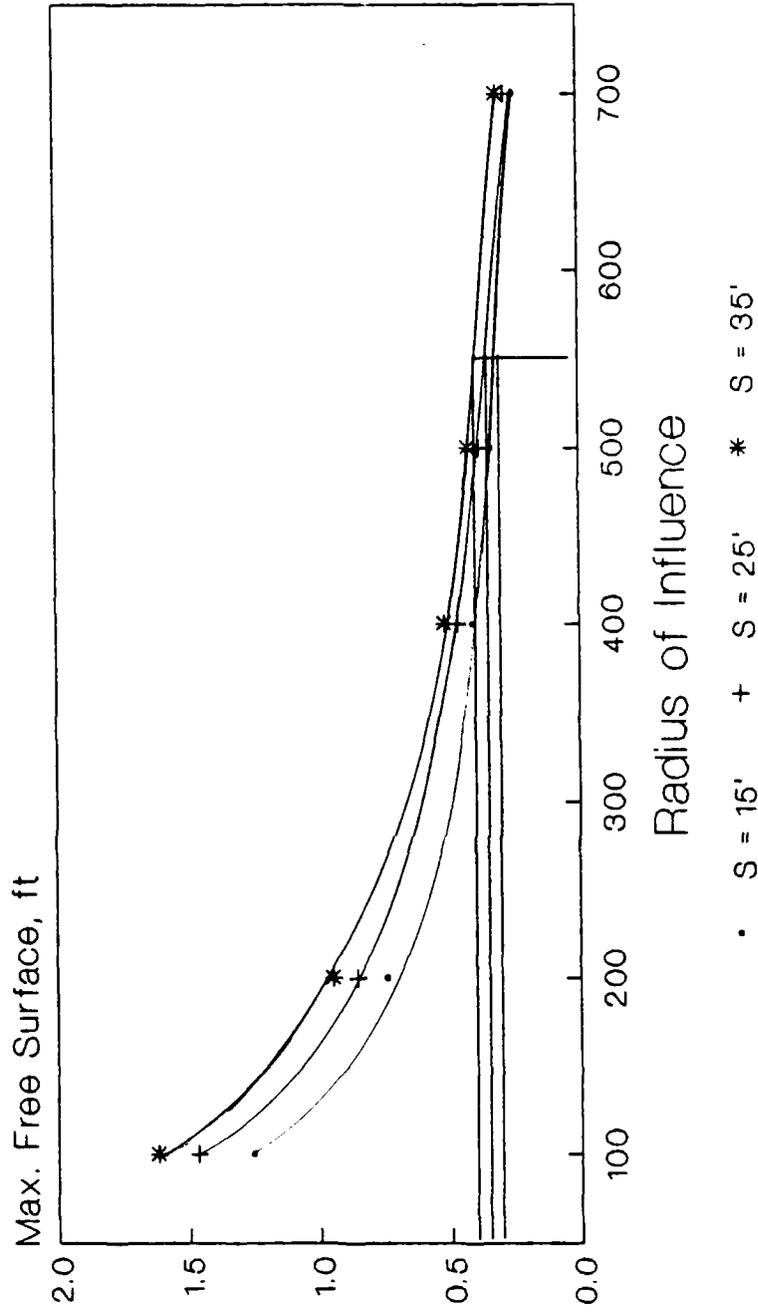


Fig. 3-11
Finding the Max. Free Surface
between trenches

MAXIMUM FREE SURFACE

(Slope 0%, $H = 60'$, $h = 10'$)

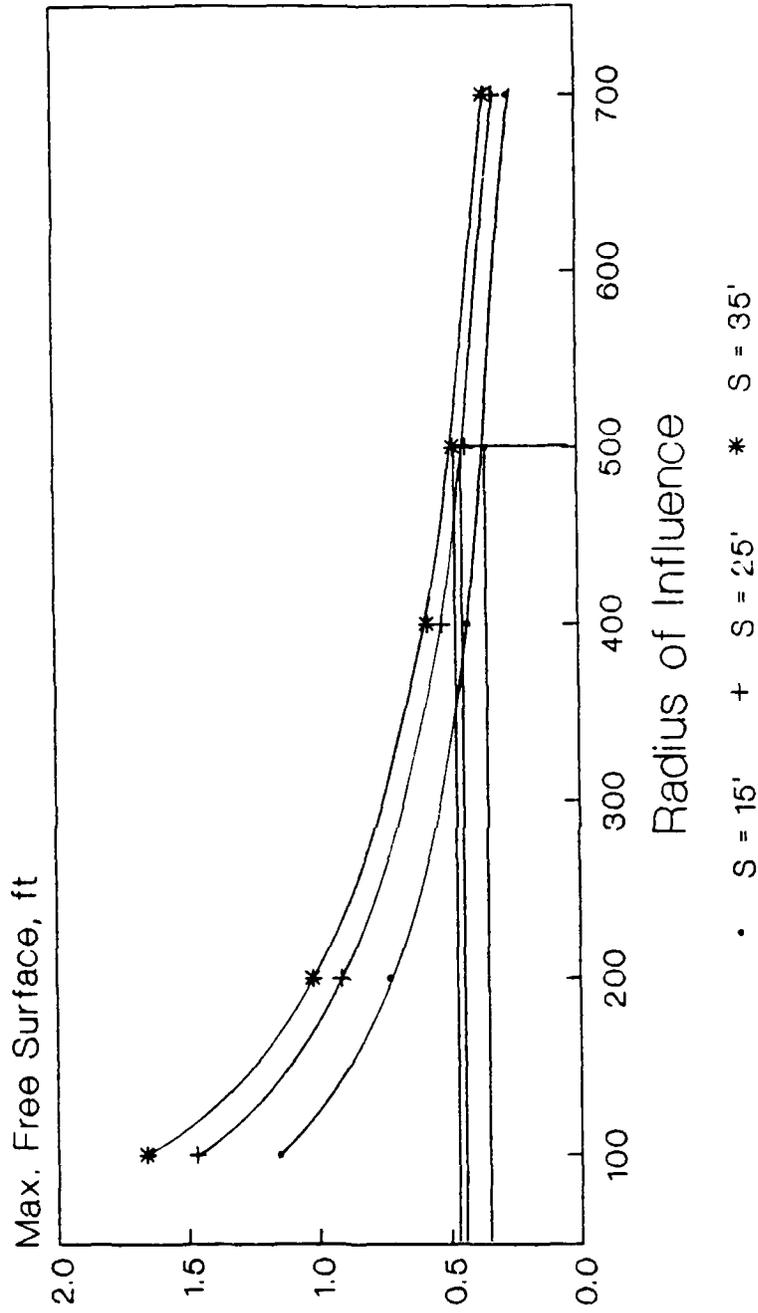


Fig. 3-12
Finding the Max. Free Surface
between trenches

MAXIMUM FREE SURFACE

(Slope 0%, $H = 60'$, $h = 20'$)

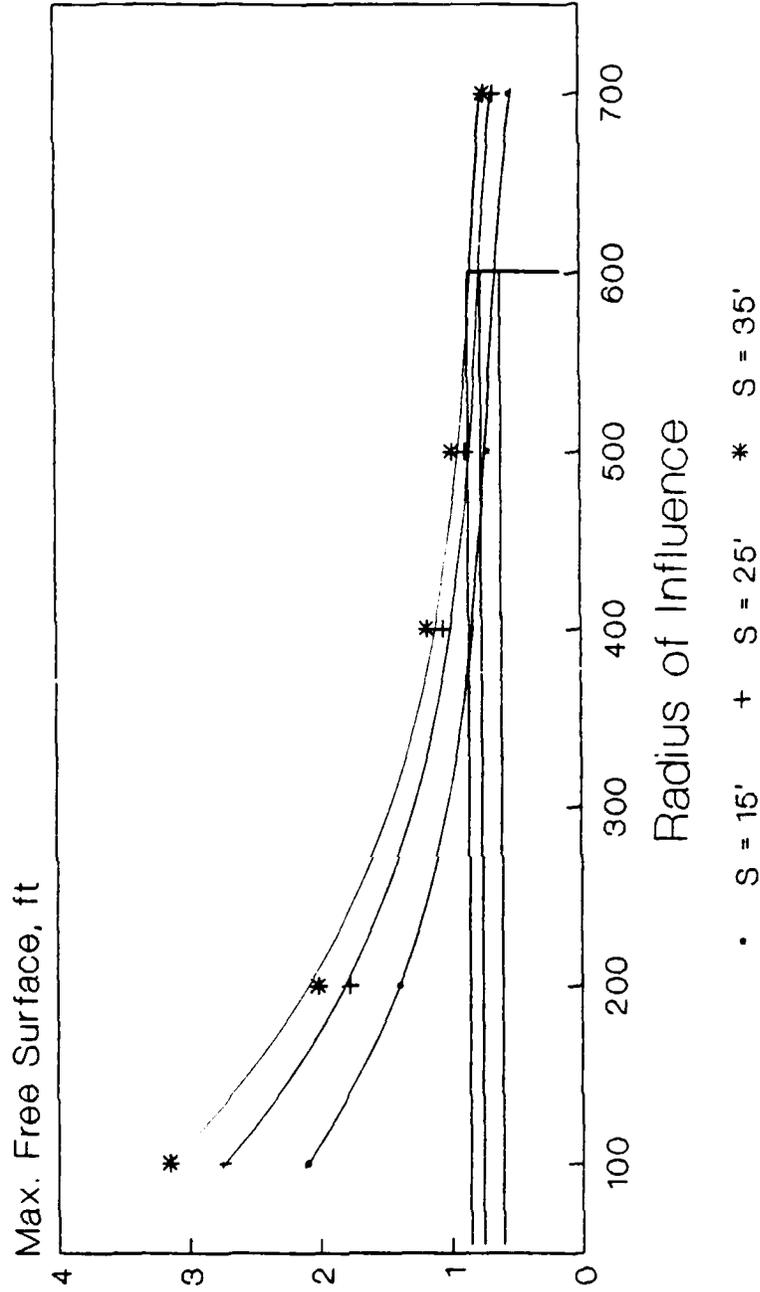


Fig. 3-13
Finding the Max. Free Surface
between trenches

MAXIMUM FREE SURFACE

(Slope 3.5%, $H = 20'$, $h = 10'$)

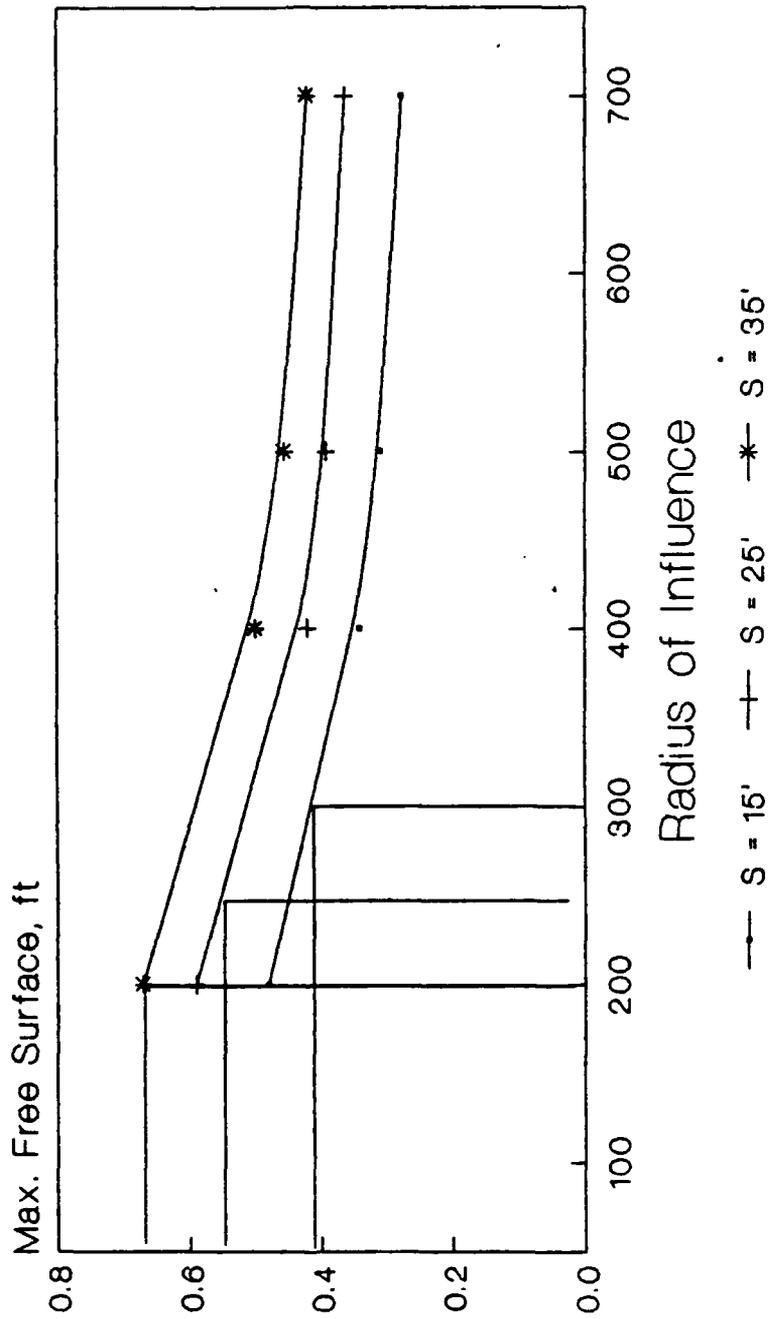


Fig. 3-14
Finding the Max. Free Surface
between trenches

MAXIMUM FREE SURFACE

(Slope 3.5%, H = 20', h = 20')

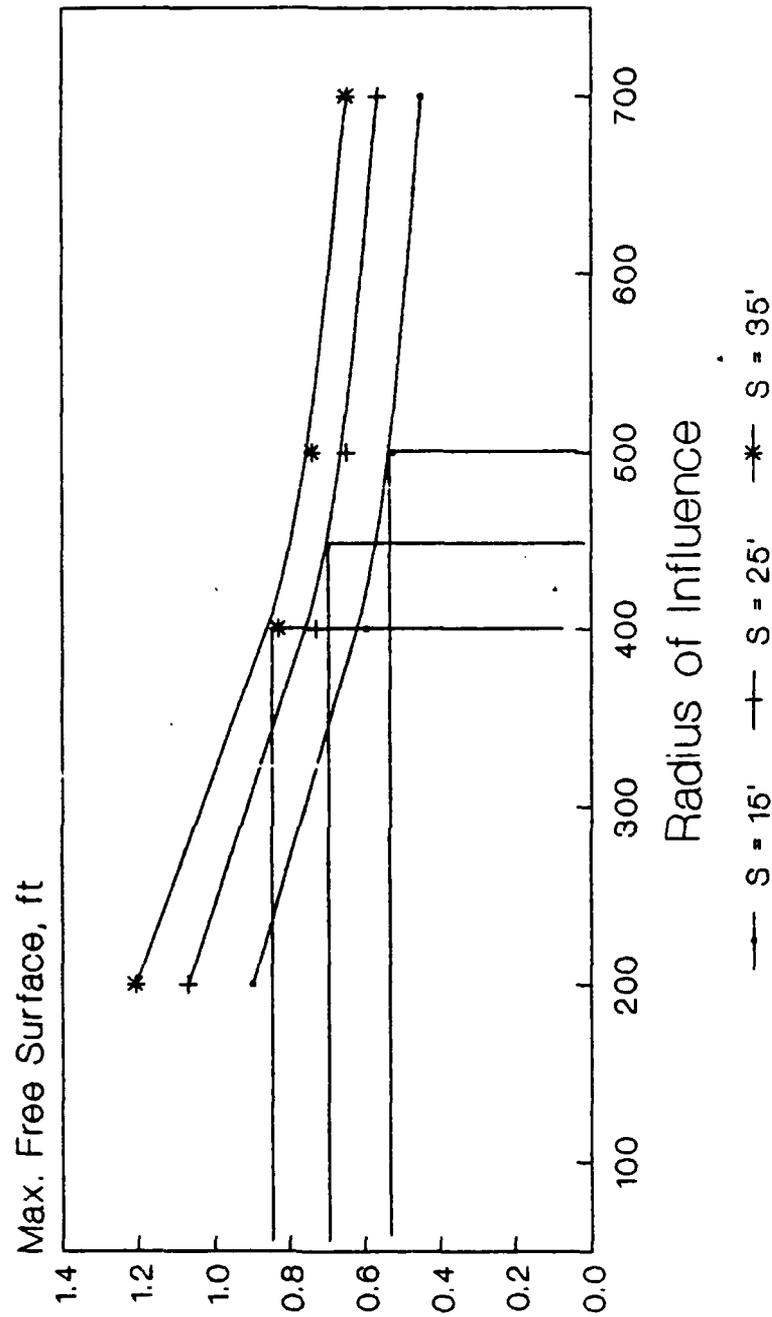


Fig. 3-15
Finding the Max. Free Surface
between trenches

MAXIMUM FREE SURFACE

(Slope 3.5%, H = 60', h = 10')

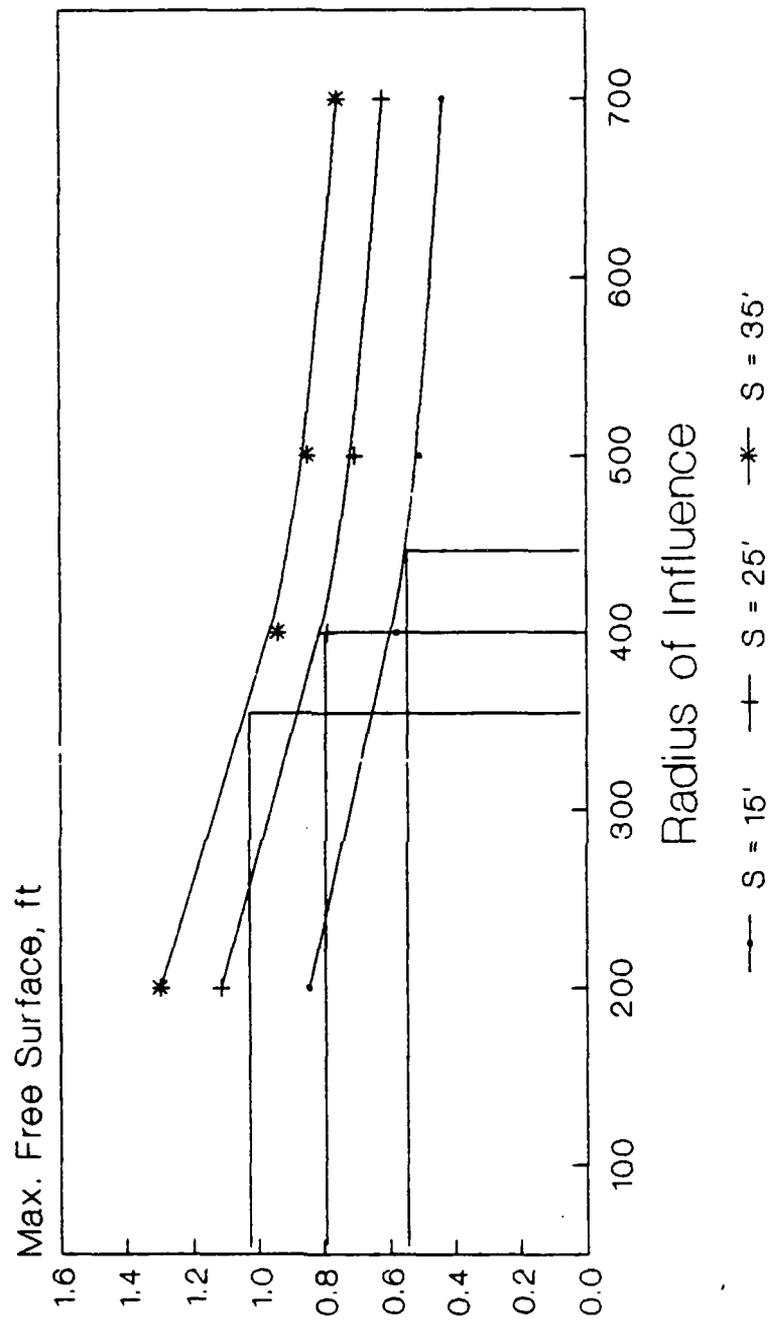


Fig. 3-16
Finding the Max. Free Surface
between trenches

MAXIMUM FREE SURFACE

(Slope 3.5%, H = 60', h = 20')

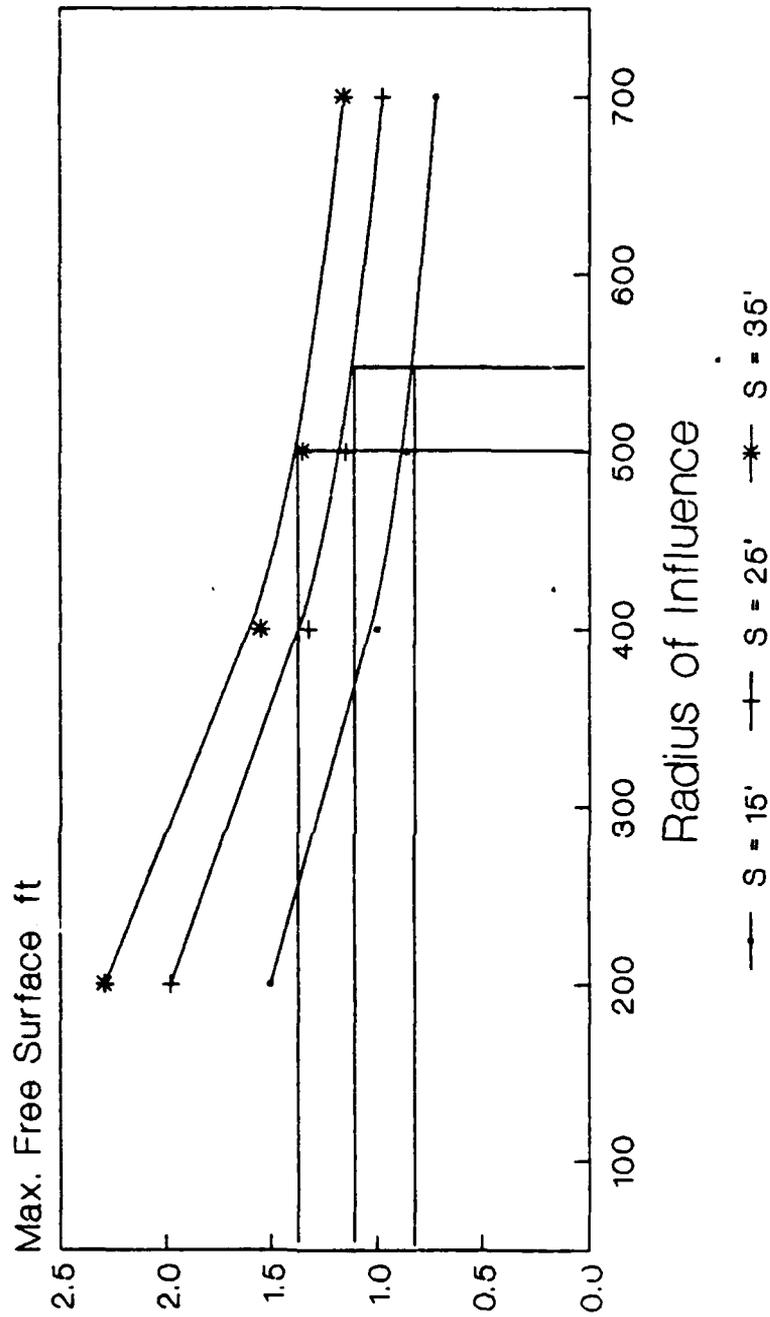


Fig. 3-17
Finding the Max. Free Surface
between trenches

MAXIMUM FREE SURFACE

(Slope 7%, $H = 20'$, $h = 10'$)

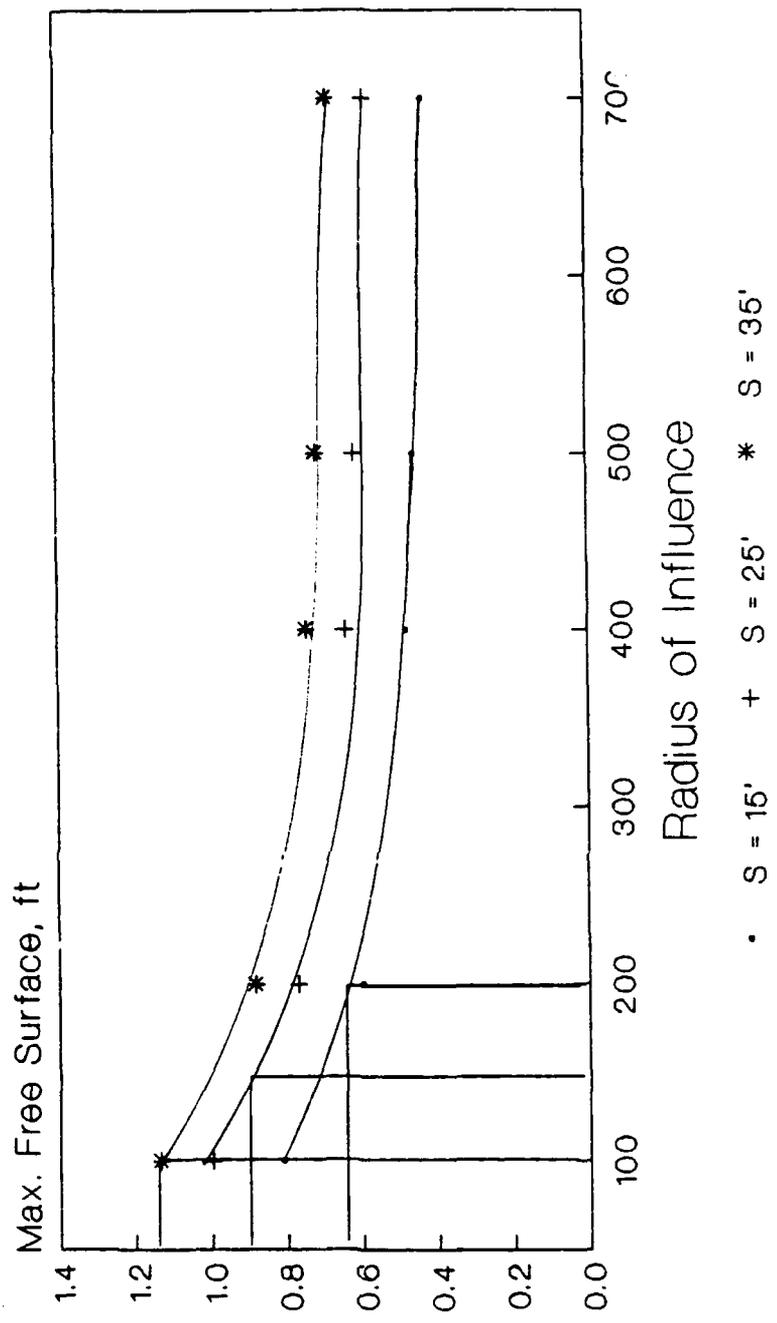


Fig. 3-18
Finding the Max. Free Surface
between trenches

MAXIMUM FREE SURFACE

(Slope 7%, $H = 20'$, $h = 20'$)

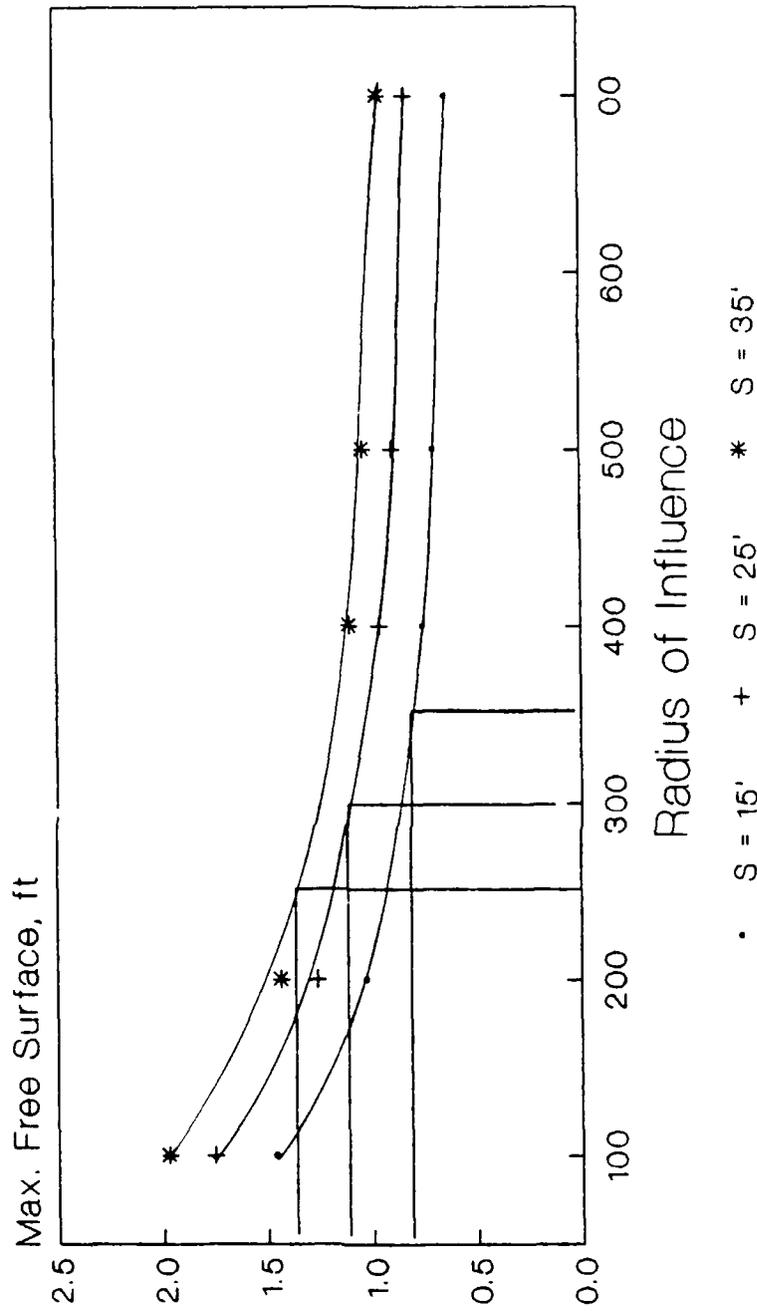


Fig. 3-19
Finding the Max. Free Surface
between trenches

MAXIMUM FREE SURFACE

(Slope 7%, $H = 60'$, $h = 10'$)

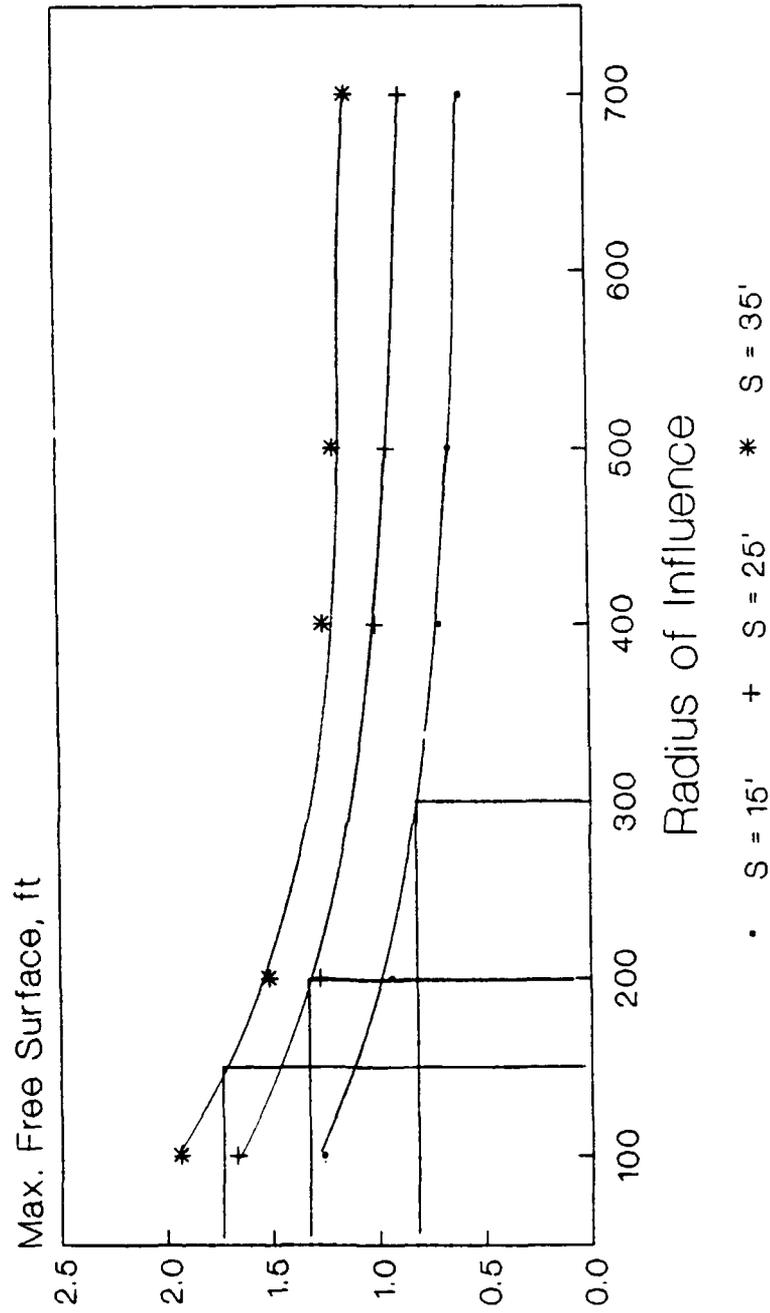


Fig. 3-20
Finding the Max. Free Surface
between trenches

MAXIMUM FREE SURFACE

(Slope 7%, $H = 60'$, $h = 20'$)

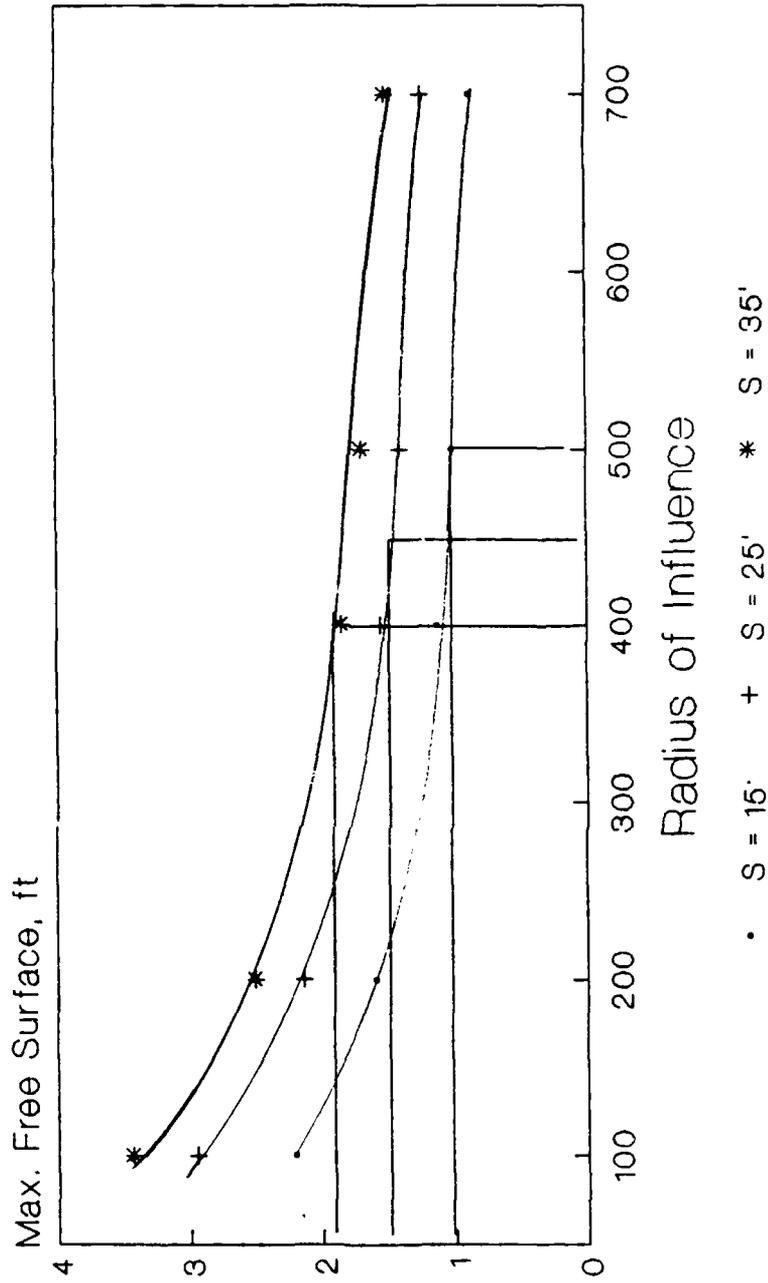


Fig. 3-21
Finding the Max. Free Surface
between trenches

V. Summary:

In summary there were three slopes considered, three spacings between drains, two elevations of trench and two free heads above the trench. That is thirty six geometries of problem, all considered under one horizontal and vertical hydraulic conductivity. While the physical dimensions of this problem are adequate to cover the majority of cases under which trench drains would be utilized, the single values of k leave room for further evaluation. With the use of dimensional analysis this study might serve to allow extrapolation of results for different hydraulic conductivities but, validation by further modeling is recommended.

CHAPTER 4

ANALYSIS OF TRENCH DRAIN DEWATERING

I. Introduction:

Modeling a foundation trench drain system with the a finite element analysis provides a myriad of results for many different conditions. For the analysis to be of use it must be presented so that future systems of trench drains can have capacities and limitations predicted from the results. This chapter is the presentation of results for use in prediction and selection of a trench drain system.

II. Results:

Chapter 3 details the input and output of this trench drain analysis. In Appendix A, Table A-1 summarizes the different variables and trench drain systems evaluated. From the data collected the total flow of a trench drain system with four drains in an isotropic soil can be determined for a range of design characteristics which are reasonable minimums and maximums. From this output information trends can be identified for the response to each variable.

The radius of influence was found from the measures described in Chapter 2. For each of the thirty six evaluated geometries of trench drain system four to six

computer models were run, each with a different trial radius of influence. Figures 2-1 through 2-12 show the results of these trials. As expected each trial of a lesser radius of influence predicted a greater total flow from the trench drain system. As the trial radius approaches the theoretically correct radius of influence the quantity of flow becomes unchanging and models the gravity flow condition accurately.

The spacing of trenches does not change the total flow of the trench drain system in a consistent pattern. The flow changed with other variables so that the single affects of spacing on flow is indistinguishable.

It is obvious that spacing directly influences the magnitude of the maximum free surface between trenches. On Table A-1 every combination of slope, trench elevation and free head has increasing maximum free surface with increasing spacing. This is consistent with expectations. Greater spacing decreases the influence of adjacent trenches. Figures 3-6 through 3-9 show that the maximum free surface in a sloping aquifer is strongly influenced by the upstream trench. The influence is even more strongly exhibited with increasing space. A larger spacing of trenches further isolates the upstream trench from drawdown influence from the inboard trenches.

In all cases the radius of influence decreased with increased aquifer slope. With greater slope, spacing of

the trenches exhibited the affect of decreasing the radius of influence. The dominant factor was the slope. The radius of influence was unchanging with spacing when the slope was zero.

Total flow did increase with the increasing slope of aquifer but, the magnitude of the change varied with the other variables so that a single affect from slope cannot be determined.

The maximum free surface increased consistently with the aquifer slope. The maximum free surface increased by 50%, for each 3.5% incremental change of slope, in every geometry considered.

Impact of different free heads above the trench was quite consistent and was normally coupled with the elevation of the trench. For constant elevation of trench the radius of influence increased with free head. In a similar manner the total flow increased with free head, with the magnitude of change impacted by the variables considered. The maximum free surface also showed a significant increase with free head when the elevation of the trench is constant.

For a constant free head with changing elevation of trench the same trends in radius of influence, total flow and maximum free surface can be seen. The magnitude of the change is not as great and the greater influence of free head can be inferred.

In this study only one drain width was considered and so the individual impact of a changing width cannot be determined. Only one vertical and horizontal hydraulic conductivity combination was studied and all studies were done on a four trench system so the affects of these single variables cannot be reported.

The many results of this study show the necessity for a form of dimensional analysis in evaluating a model affected by many variables. Some trends can be predicted from a couple of variables but, a complete prediction of performance or trend is not possible without a dimensional analysis.

III. Results of Predictive Formulas:

It is not surprising that no single numeric method exists for the evaluation of a trench drain system of four drains, in a sloping aquifer. This study attempts to provide that solution but, do other, existing solutions serve the need? In Chapter 2 several formulas were referenced in the discussion of determining a radius of influence. In this section several formulas are evaluated. The formulas below are presented with the variables used in this study rather than as presented in the source. A comparison of the results for the below methods with the results of the finite element analysis are in Table 4-1.

a.)
$$Q_p = (.73 + .27(h/(h+H)) Kx((h+H)^2 - h^2)/L$$

Q_p =total flow, h =free head, H =trench elevation, x =trench length, K = permeability, L = radius of influence (use consistent units)

The above formula (Leonards, pg 273) has the advantages of being for a partially penetrating slot in an unconfined aquifer. The disadvantages are that it has no provisions for a sloped aquifer, multiple trenches, trench width or means for calculating the maximum free surface. The radius of influence is a value of input to this formula.

b.) Figures 36, 61, 68 and 69 (Moulton)

The referenced charts offer allowances for sloping aquifer, two drains, partial penetration of the aquifer and a means of calculating a maximum free surface between drains. Some disadvantages of the methods are the lack of trench width, no allowance for more than two drains and a half space solution to the zero slope portion. The radius of influence is an input variable to solution. As listed in Chapter 3 the recommended radius of influence is $3.8 \cdot h$. This value yields a maximum radius of influence of 76 feet for this study. This value was much less than used throughout the study and yielded results far greater than predicted from the finite element analysis. In Table

4-1 the radius of influence used was that from the finite element analysis which yielded results much closer to those of the other calculations.

c.) $Q/x = K((H+h)^2 - h^2)/L$ ((a) Powers, pg 100)

Q= total flow, x= trench length, K= permeability, H= trench elevation, h= free head, L= radius of influence
(Use consistent units)

This method is a traditional trench solution. It does not make allowance for partial penetration of the aquifer, multiple trenches, trench width or aquifer slope.

d.) $G = S_y L q / K H^2$ and figures 18(b) and (c)

(Freeze, pg 261) G= dimensionless product, S_y = Specific Yield, L= radius of influence, q= total flow per unit width, K= permeability, H= aquifer thickness (use consistent units)

This solution is for a partially penetrating trench. Once again this method makes no provision for multiple trenches, trench width, sloping aquifer. In addition the Specific Yield is used adding another variable, this one normally varying between .01 and .3 (Freeze, pg 61).

Each of the above methods have several disadvantages and were not developed for use in the evaluation of a trench drain system. Assuming that the finite element analysis is the most accurate of the means of evaluation tried it is obvious in Table 4-1 that no single formula

TABLE 4-1 Summary of Predictive Methods
Summary

	A	B	C	D
Slope	0	3.5	3.5	7
Spacing (ft)	35	15	35	25
Trench El (ft)	60	20	60	20
Free Head (ft)	10	20	20	10
 (Mansur, pg 273)				
total flow (ft ² /day)	0.5	0.46	0.81	0.55
 (Moulton, pg 120 & 130)				
total flow (ft ² /day)	0.49	0.22	0.73	0.42
 (Powers, pg 100)				
total flow (ft ² /day)	0.66	0.53	1.02	0.66
 (Freeze, pg 261)				
total flow (ft ² /day)	5.88	0.64	5.12	2
 Anal Seepage Program				
total flow (ft ² /day)	0.14	0.19	0.25	0.27
Radius of Infl (ft)	500	500	500	150
 Trial Radius 200'				
Total Flow (ft ² /day)	.3	.45	.54	.26

approximates the solution to the problem very closely. Of the evaluated methods the Moulton method, using the radius of influence as determined by the finite element analysis was the most accurate. It is worth noting that with no other means of selecting a radius of influence the value determined in this study was used for each method. This approximation would certainly affect the results. Appendix E is a discussion of the affect of arbitrary selection of radius on total flow and free surface height.

IV. Prediction of Trench Drain Performance:

The prediction of total flow and maximum free surface is possible through the use of results presented in a dimensionless form. As a trial some runs were done to explore the affects of anisotropy and number of trenches. These results are discussed below.

Any prediction of flow characteristics requires an evaluation of the radius of influence. Figures 4-1 through 4-3 are useful for predicting the radius of influence from the trench elevation, free head, slope of aquifer and the trench spacing. These figures are only appropriate for an isotropic condition in a four trench system with a trench width of 1.5'. Use of the figures will frequently require several interpolations.

Radius of Influence

(Four trench drains, Slope 0 to 7%
 $K_v = K_h$, trench width 1.5')

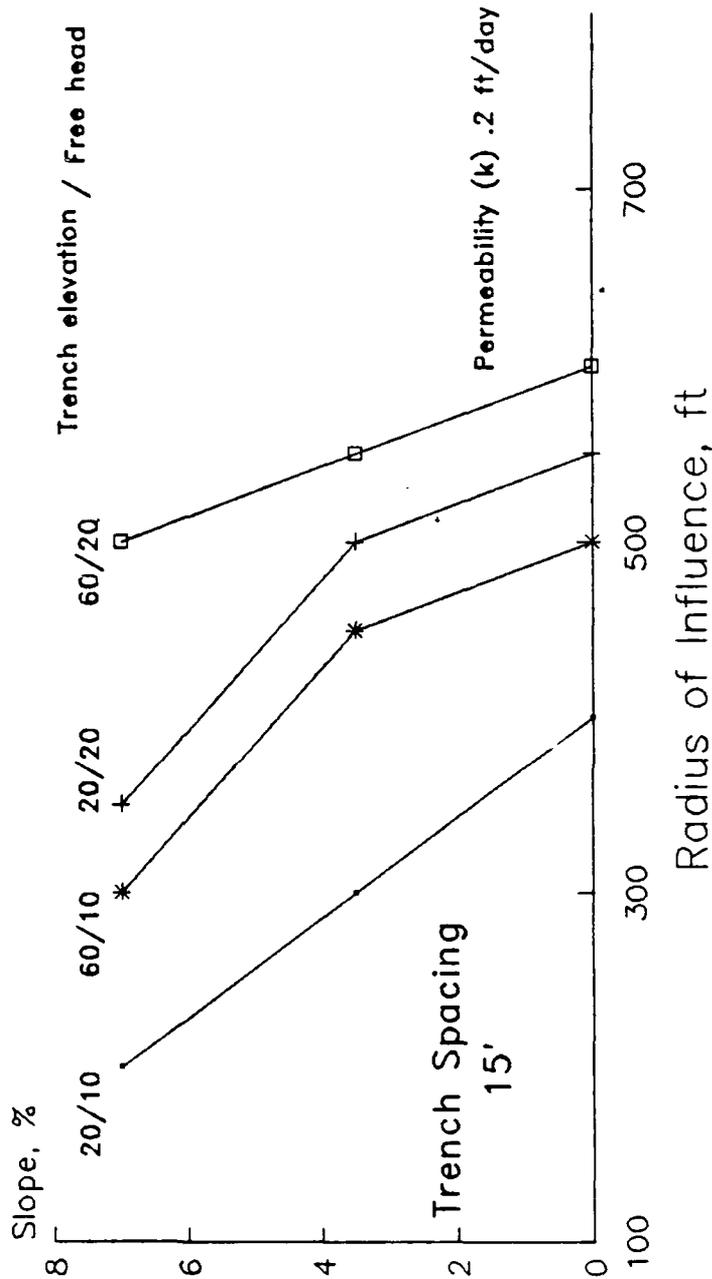


Fig. 4-1
 Predicting the radius of influence

Radius of Influence

(Four trench drains, Slope 0 to 7%
 $K_v = Kh$, trench width 1.5')

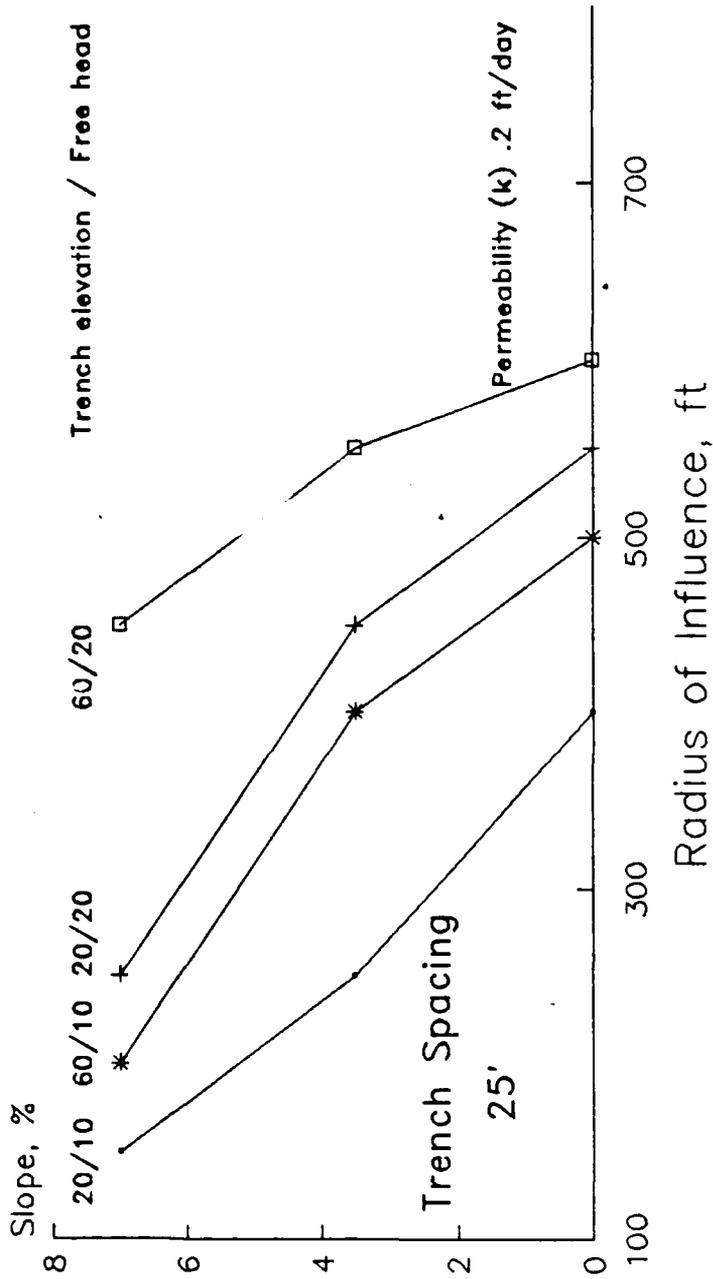


Fig. 4-2
 Finding the radius of influence

Radius of Influence

(Four trench drains, Slope 0 to 7%
 $K_v = Kh$, trench width 1.5')

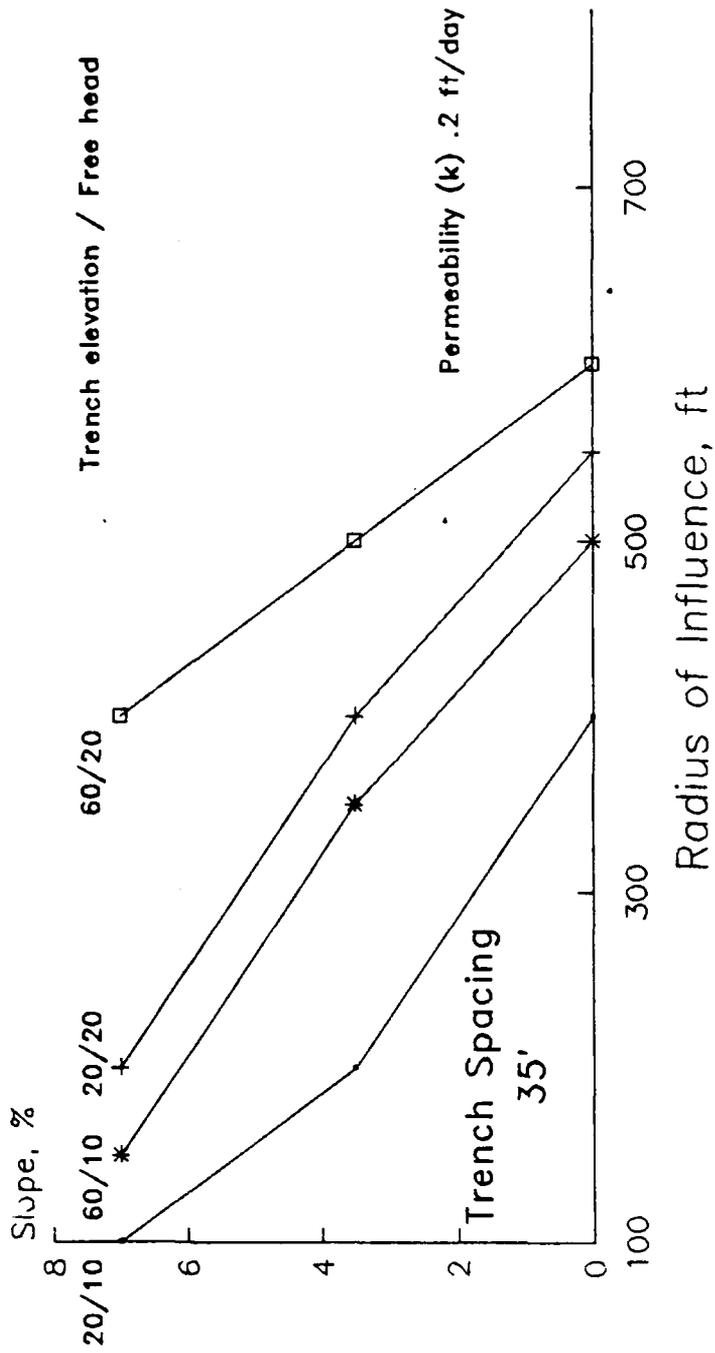


Fig. 4-3
 Finding the radius of influence

To use figures 4-1 through 4-3 the following example will be useful.

Example 4-1: Find the radius of influence for a four trench system with trench width of 1.5' and $K_v/K_h = 1$ with $K = .2$ ft/day. The trench elevation is 40 feet, the free head is 15 feet, the trench spacing is 30 feet and the aquifer slope is 4%.

a. Figure 4-4 is annotated from Figure 4-2. Follow this figure through the following steps.

b. At slope = 4% on Figure 4-2 interpolate between the lines labeled 20/10 and 20/20 as well as between 60/10 and 60/20. These are the points for trench elevations of 20 and 60 feet with a free head of 15 feet. The radii of influence for these two points are 330 feet and 456 feet.

c. Again at slope = 4% interpolate between the above two points to find the radius of influence for a trench elevation of 40 feet and a free head of 15 feet with a spacing of 25 feet. This radius of influence is 394 feet.

Radius of Influence

(Four trench drains, Slope 0 to 7%
 $K_v = K_h$, trench width 1.5')

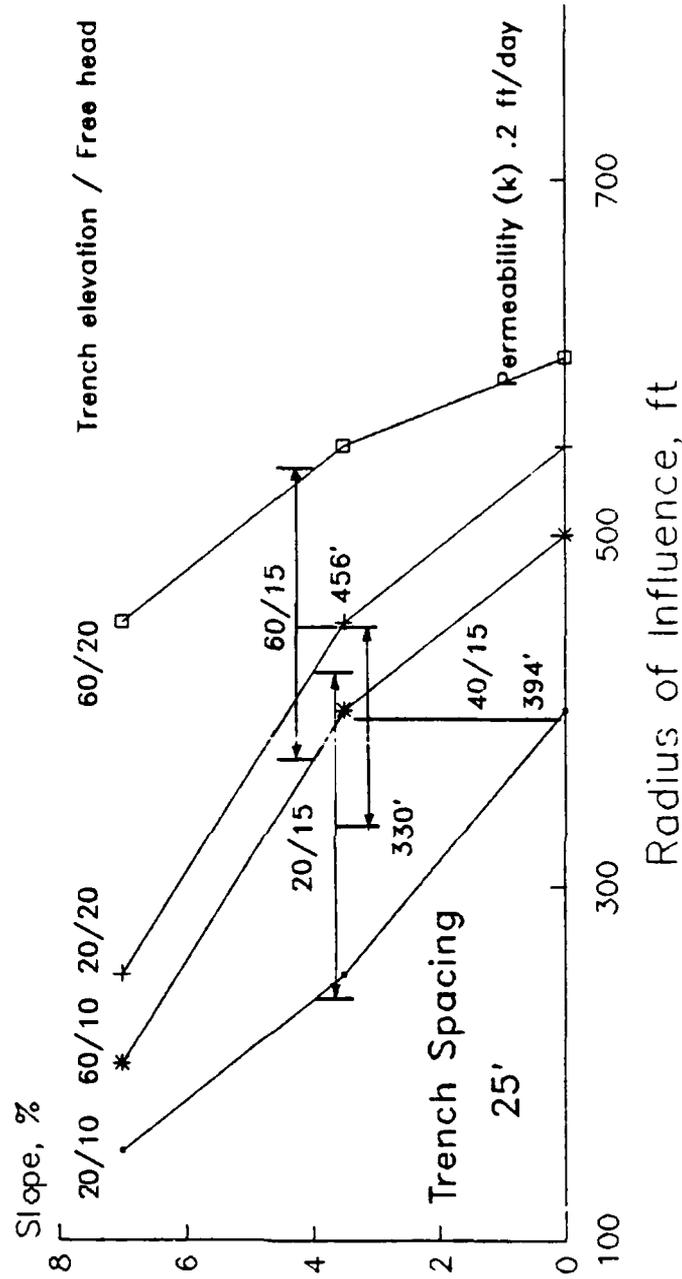


Fig. 4-4
 Finding the radius of influence
 for example 4-1

d. Follow the above procedure again on Figure 4-3 to get a radius of influence of 344 feet when spacing is 35 feet.

e. For a spacing of 30 feet interpolate between the results of steps c. and d. above to get a final predicted radius of 369 feet.

As an alternate method a rough selection of 350 or 400 feet will not make a significant difference in the following calculation method. As discussed in Chapter 2 the radius of influence is an extremely variable value, often approximated only within an order of magnitude. One suggested method (Moulton, pg 66) has the radius of influence estimated as 3.8 times the free head. In this example that would predict a radius of only 53 feet, one seventh of that from this study but, within one order of magnitude.

In Chapter 2 the derivation of the dimensionless product used in this study was reviewed. The product which best presented the behavior of total flow and maximum free surface with the changing variables of the problem geometry was:

$$Ld/h(h+H) \quad (2)$$

Where L = radius of influence, d = trench width, h = free head and H = trench elevation as shown on Figure 3-4. Using consistent units for the variables yields a dimensionless product.

Figures 4-5 and 4-6 are total flow and maximum free surface, respectively against the dimensionless product for the considered geometries. In both plots an acceptable curve fit is possible. The points are aligned with the largest aquifer slope to the left and the zero sloped aquifer to the right. This observation is for interest only as the dimensionless product provides sufficient accuracy with the sloping aquifer influence represented by the values of total flow, maximum free surface and radius of influence. From the previous example:

- a. Calculate $Ld/h(h+H)$. For this problem using the above $L = 369$ feet,
 $Ld/h(h+H) = 369' * 1.5' / 15' (15' + 40') = .671$
- b. From Figure 4-5 total flow $q = .25 \text{ ft}^2/\text{day}$
- c. From Figure 4-6 maximum free surface
 $F = .9 \text{ ft}$

As a check of the accuracy of this method to predict the output of the finite element analysis six sample runs were conducted. The values of the variables and the results of the finite element analysis are shown in Table

TOTAL FLOW

(Four trench drains, 0 to 7% slope,
 $K_v = Kh$, trench width 1.5')

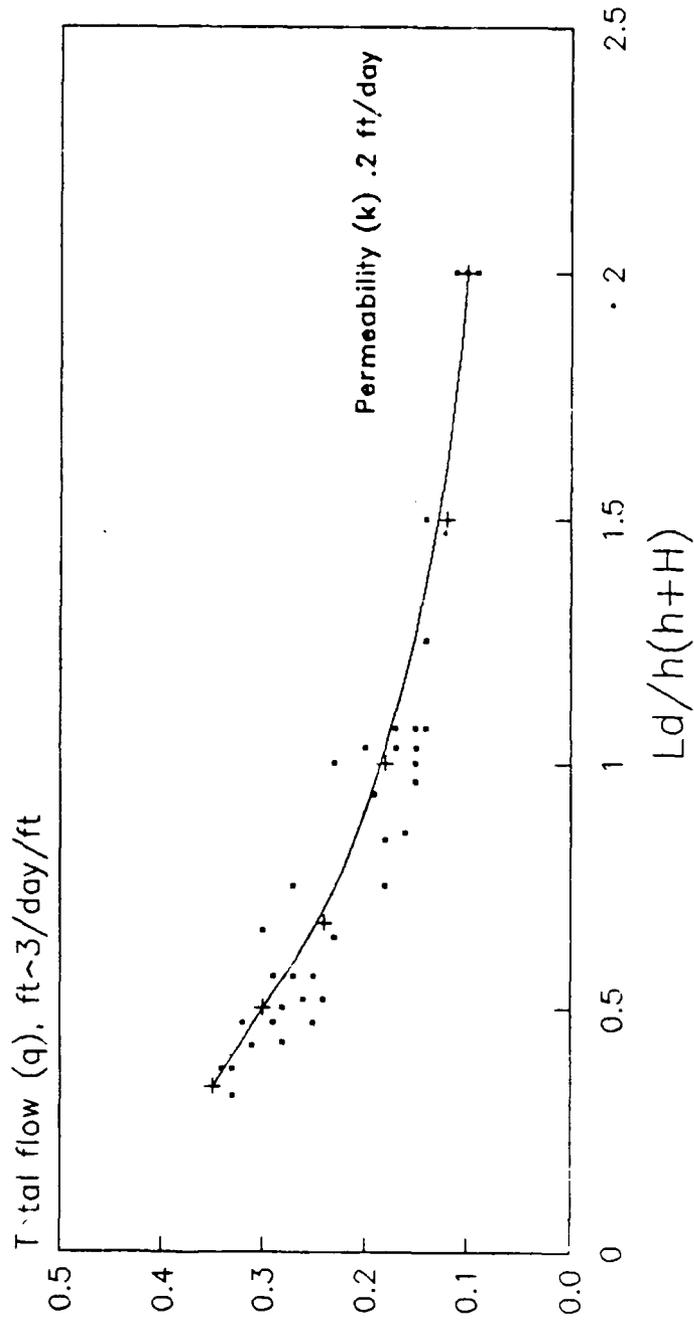


Fig. 4-5
Predicting flow from a
dimensionless product

MAXIMUM FREE SURFACE

(Four trench drains, Slope 0 to .7%
 $K_v = Kh$, trench width 1.5')

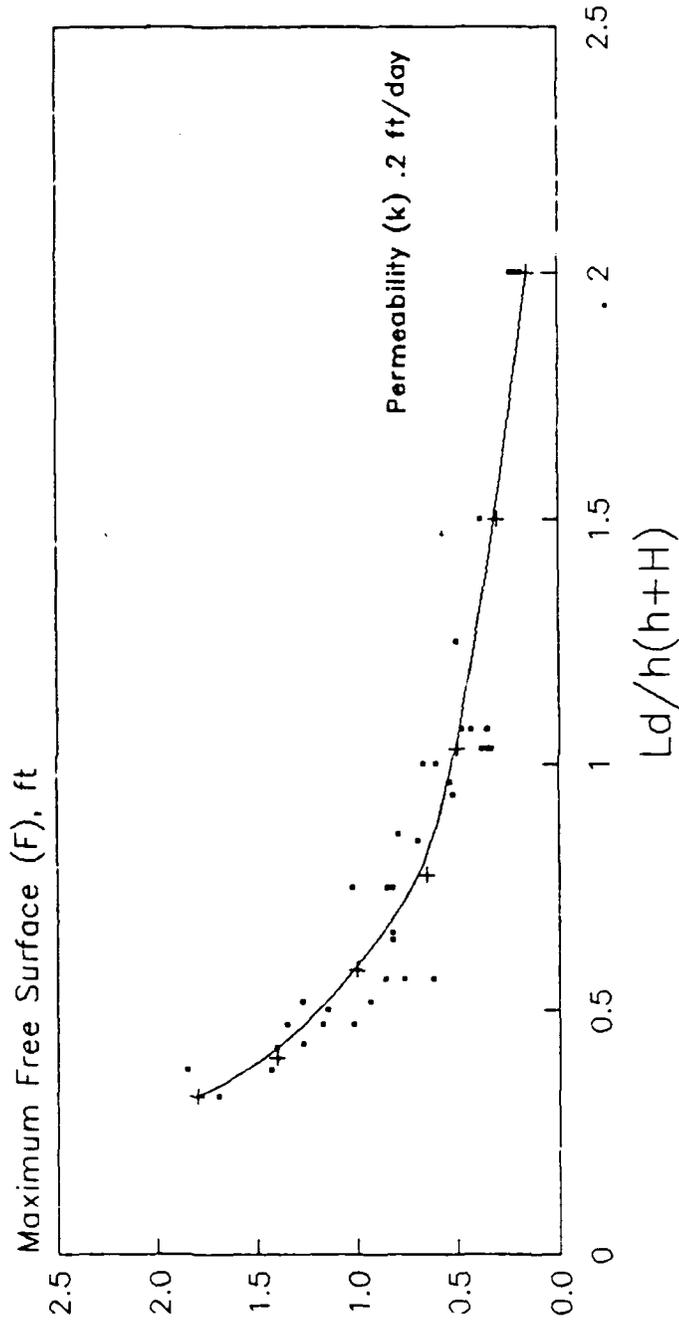


Fig. 4-6
 Finding the maximum free surface
 from a dimensionless product

A-2. For this analysis three trial radii of influence were used for each sample run. The theoretically correct radius of influence, total flow and maximum free surface were taken from plots similar to Figures 2-1 and 3-10.

The determination of the theoretically correct radius of influence is done under an arbitrary standard to an accuracy of fifty feet. From Table A-2 the prediction of total flow and maximum free surface agree with the results of the finite element sample runs. This is excellent accuracy in selecting the radius of influence. This method is acceptable for an isotropic soil with a four trench system.

Figures 4-5 and 4-6 were prepared assuming an isotropic condition. As a matter of interest several finite element runs were done modeling a four drain system with various conditions of anisotropy. Normally soils are anisotropic with K_v/K_h between .1 and .33. The results of these sample runs are shown on Figures 4-7 and 4-8, where the affects of differing hydraulic conductivity and anisotropic soil are explored.

From Figure 4-7 it appears that different lines, nearly parallel, exist for a four drain systems with the line of largest total flow having the highest hydraulic conductivity and the line of lowest flow with the lowest hydraulic conductivity. The lines of differing conductivity may converge to the left side of the plot.

TOTAL FLOW

(Four trench drains, 0 to 7% slope,
 $K_v \neq Kh$, trench width 1.5')

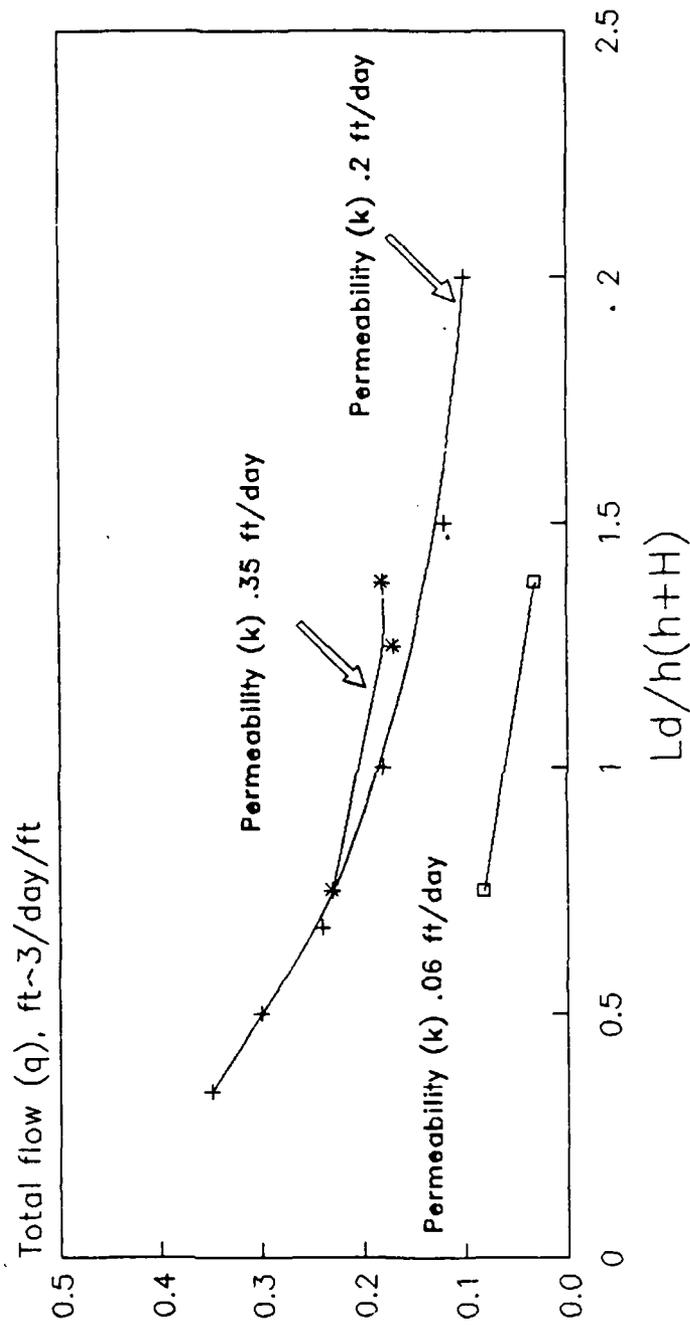


Fig. 4-7
Permeability and Flow with a
dimensionless product

MAXIMUM FREE SURFACE

(Four trench drains, Slope 0 to 7%
 $K_v \neq K_h$, trench width 1.5')

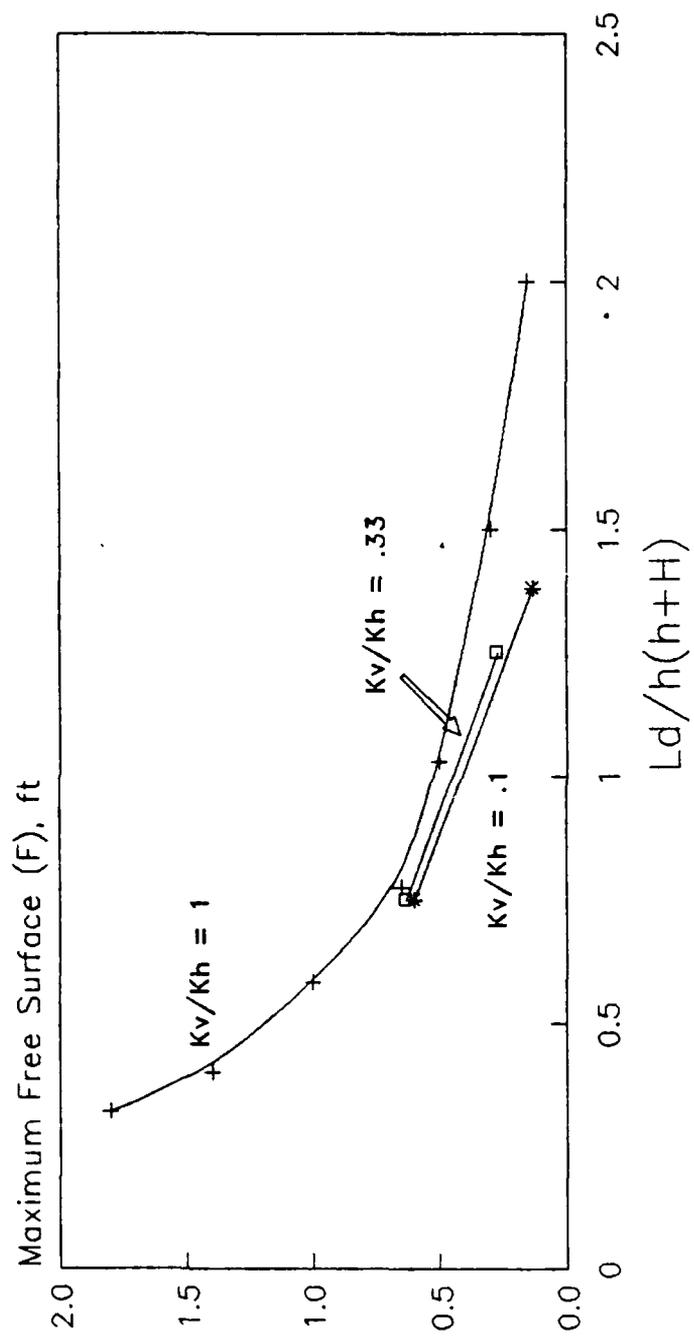


Fig. 4-8
 Anisotropy and maximum free surface
 from a dimensionless product

The degree of anisotropy appears to have no consistent pattern.

Figure 4-8 shows the opposite influence. The degree of anisotropy, represented by K_v/K_h , would have parallel lines with decreasing maximum free surface as the degree of anisotropy decreases. The lines of this plot may also converge to the left as $Ld/h(h+H)$ decreases.

Another area of interest is the affect of a differing number of trench drains. As a means of predicting the ultimate affect of systems with more or less drains then the four evaluated. Figures 4-9 and 4-10 show the results of three runs of a three trench system. While not conclusive it is likely that the line for a three trench system is just below the four trench line. With further study it might be possible to extend the results of a four drain analysis based on the paralleling trends of lines for the different trench configurations.

TOTAL FLOW

(3 & 4 trench drains, 0 to 7% slope
 $K_v = Kh$, trench width 1.5')

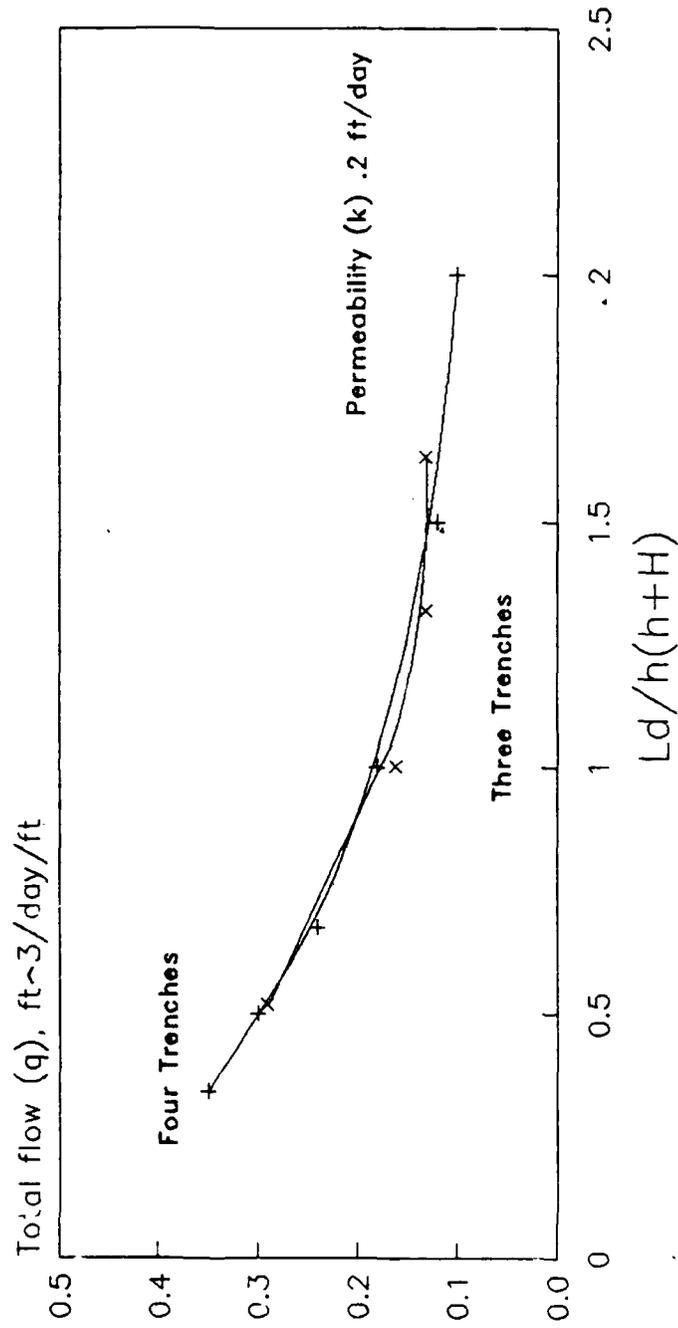


Fig. 4-9
Comparison of Three Drain System
in dimensionless product

MAXIMUM FREE SURFACE

(3 & 4 trench drains, Slope 0 to 7%
 $K_v = K_h$, trench width 1.5')

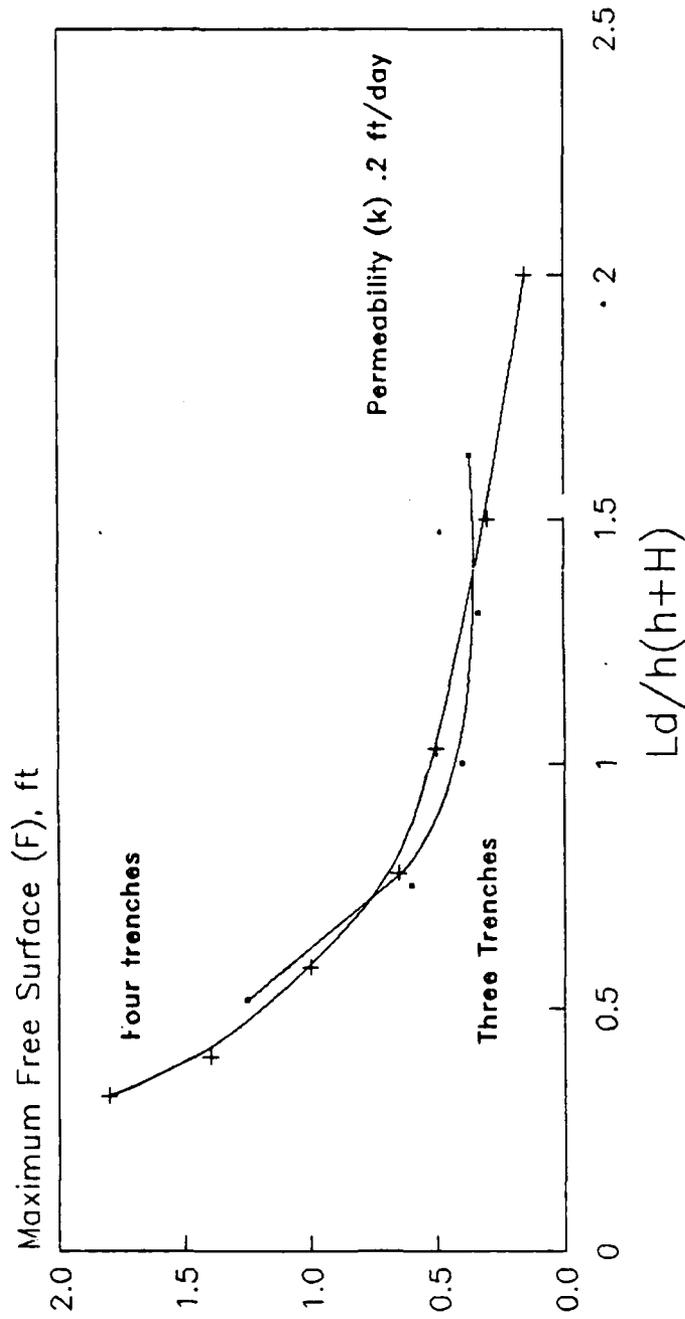


Fig. 4-10
 3 & 4 Trenches for maximum free surface
 from a dimensionless product

This study has developed an effective method for determining the total flow and maximum free height for a trench drain system, knowing the geometry of the problem. It appears probable that anisotropic conditions, different hydraulic conductivities and trench systems with other than four drains can be included into this type of evaluation with some further research.

V. Comparison of Trench Drain with Blanket Drain:

An alternative to the trench drain system for dewatering beneath a foundation is the blanket drain. A blanket drain system is similar to the trench drain system as it is a mass of open graded stone or gravel isolated from the soil by a geosynthetic filter material and has slotted collector pipes to carry water to a sump for removal. It is different in geometry. The blanket drain is a single rectangular cross section which dewateres the surrounding soil to the depth of the bottom of the section. The trench drain uses less gravel by extending the dewatering depth down with narrow trenches extending from a thin base of gravel across the bottom of the foundation (Figure 3-4).

The blanket drain does an excellent job of dewatering beneath a foundation and has the advantage of easier construction. The biggest difference between the two systems in a practical application is the cost. The trench system requires more detailed labor and excavation

while the blanket drain requires more gravel. To do a cost comparison of the two methods a standard foundation size was necessary to determine the excavation, placement and compaction productivity rates. In this study a foundation of 100 feet by 200 feet was used, only for the establishment of unit costs of labor.

The evaluation is done based on a set slab elevation and a predetermined base of trench or blanket drain. That is the blanket drain will have to be thick enough to dewater to the depth of the trench drain without lowering the foundation. A basic cost to this evaluation was the cost of gravel (#57 stone) which goes for \$8.30/ton in the Atlanta area. Labor costs used were \$20/hr for an equipment operator and \$16/hr for a laborer (both rates including overhead and fringes). Productivity values came from the Means estimating guide for 1989. The cost of equipment rentals were approximated from the same guide. The cost of the geosynthetic filter material was estimated as \$0.70/yd² from discussions with suppliers and engineers in the Atlanta area.

The cost data was input into a spreadsheet with a variety of possible trench drain configurations. The costs were calculated for both the trench drain and an equivalent blanket drain for several different systems each with more drains. Table 4-2 is a copy of one such trial. With the cost of gravel so much higher than the

filter material the ratio of trench drain cost to blanket drain cost was less than one in all cases.

With a blanket drain at a shallow elevation the cost comparison is more likely to recommend a blanket drain system. Figure 4-11 is a summary of such a comparison. To use a thickened blanket drain will sacrifice drawdown capacity in exchange for some construction ease and cost benefits. The decision will depend on the application.

TABLE 4-2

Trench and Blanket Drain Costs

Excavation unit costs			Material costs (in place)			
Trench	0.4	\$/cu.ft	Geosyn	0.08	\$/sq.ft	
Blanket	0.08	\$/cu.ft	Gravel Tr	0.45	\$/cu.ft	
			Gravel B1	0.9	\$/cu.ft	
				per unit lngth		
Spacing	Trench Width	Trench Depth	Number of Trenches	Trench Total \$	Blanket Total \$	
15	1.5	1	30	38.25	508.96	
15	1.5	4	30	153	1920.64	
15	2.5	1	30	63.75	540.76	
15	2.5	4	30	255	2040.64	
25	1.5	1	30	38.25	816.36	
25	1.5	4	30	153	3080.64	
25	2.5	1	30	63.75	848.16	
25	2.5	4	30	255	3200.64	
35	1.5	1	30	38.25	1123.76	
35	1.5	4	30	153	4240.64	
35	2.5	1	30	63.75	1155.56	
35	2.5	4	30	255	4360.64	

Cost, Trench vs Blanket (Same size foundations, dewatering to different depths)

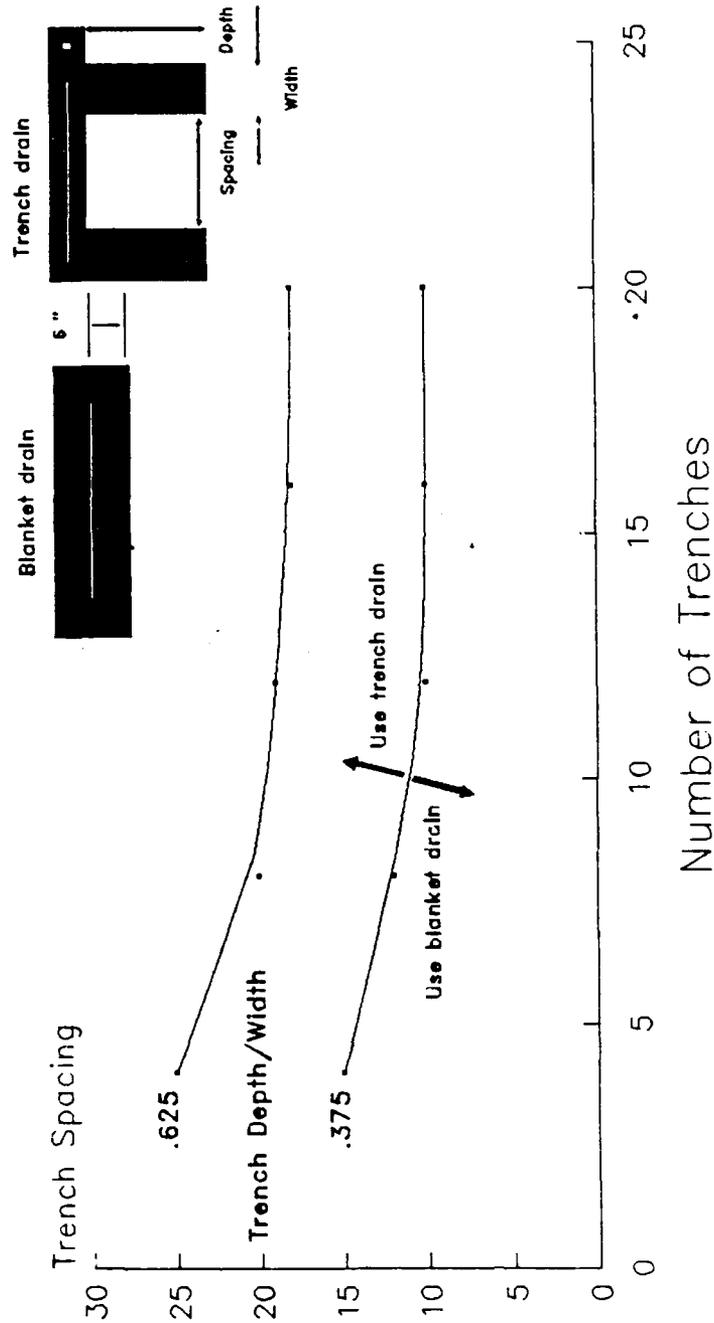


Fig. 4-11
Spacing for economic use of Trench
Drain, dewatering to greater depth

VI. Conclusions:

In this chapter a method for predicting the results of a finite element analysis of a trench drain system for isotropic soil and four drains is presented. A rough approximation has been made to show the possible impact of anisotropy and different trench configurations. Empirical data is not available to validate or modify the predictions of the Aral Seepage Program for a trench drain system. Compared with other slot drain solutions it appears that the finite element solution predicts lesser flows and is so less conservative.

The use of a trench drain system can be justified economically over a blanket drain system in some configurations. The brief evaluation of this chapter provides a simple comparison method for the relative cost differences of the two systems.

CHAPTER 5
CONCLUSIONS

I. Introduction:

In this study the trench drain system was evaluated for thirty six configurations using a finite element analysis program. The results of the analysis were used under dimensional analysis to form a method of predicting the results of a similar analysis for any configuration of a trench drain system within the limits of the study. The final portion of the study was to evaluate the cost of a trench drain system as compared with the blanket drain system for use in a drain beneath a foundation.

II. Trench Drain System Analysis:

The results of the finite element analysis could not be validated by test or field data nor, did the formulas available show close agreement with the results of the analysis. It would be useful if the actual outflow of a trench drain system were measured and the radius of influence of drawdown determined.

This study was limited to isotropic conditions and a four drain system. The affect of other conditions was briefly explored but, a more complete study is necessary before the results are extrapolated to conditions of many drains or variable soils. Initial expectations are that results of Figures 4-7 through 4-10 will be consistent with results of a more complete run of

variables. Whether more than four drains have significantly different shape than the four and three drain curves will be most important when the cost comparison of trench and blanket drains is considered from Figure 4-11.

The one recurring constant in the reference material on dewatering is the variable nature of the radius of influence. For the narrow conditions evaluated in this study reasonable estimations of the radius of influence are possible from Figures 4-1 through 4-3. The earlier recommendations of field observations and computer modeling with other ranges of variables would expand the information available for predicting the radius of influence.

The permeability used in this study, 0.2 ft/day is consistent with the soil in the Atlanta area. If the trench drain system is to be used in a greatly more permeable soil the results may be significantly different. It would not be recommended to use a trench drain in a very porous sand or gravel just as an open sump is not satisfactory to dewater a site of that composition. Establishing the upper and lower bounds of permeability for practical use of trench drains is a most useful recommendation for further study.

III. Predictive Method:

The predictive method using Figures 4-1 through 4-6 work well in predicting the results of the finite element analysis. The forms are easy to use and adapt readily to drain configurations within the range evaluated. The range of variables were selected

to match the conditions under which a trench drain system is normally used. Extrapolation of the results beyond these values may be of limited practicality and questionable accuracy.

The prediction of the maximum free surface at a low dimensionless product ($Ld/h(h+H)$) should be treated with great care. When the product is less than 0.5 the curve rises rapidly and the maximum free surface exceeds 1.25 feet only in this range. The maximum free surface is of concern only when the water level approaches the shallow blanket immediately beneath the slab, approximately one foot for most trench systems. The curve for the maximum free surface was roughly aligned with the 7% slope values at the left end and the 0% slope values on the right. For large aquifer slopes the curve may approach vertical and might be sufficient reason to avoid the use of a trench drain system in such an aquifer.

IV. Cost Comparison:

If the necessary depth of dewatering is to the depth of the trench drain system a blanket drain cannot compete on an economic basis. If a very shallow level of dewatering is required beneath the foundation it would not be practical to install a trench drain system. Trenches of under one foot depth would require individual consideration. By the results of Figure 4-11 it is apparent that even sacrificing the depth of dewatering is not sufficient to turn the advantage to blanket drains in all cases.

V. Evaluation:

The results of this study have satisfied the stated intentions. Results and input were reviewed with care and show consistent and reasonable trends. Appendix C is a brief description of the method of compilation of data, preparation of data files and execution of program commands. Also included in Appendix D is a storage disk for an IBM compatible computer with the spreadsheets of results and the data files used.

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APPENDIX A
SUMMARY OF PROGRAM COMPUTER RUNS

APPENDIX A

FINITE ELEMENT COMPUTER RUN SUMMARY

	Trench Spacing	Trench Elevation	Free Head	Radius of Influence	Total Flow	Max Free Surface	Number of Trials
Slope = 0%							
	15	20	10	400	0.11	0.18	6
	15	20	20	550	0.2	0.33	6
	15	60	10	500	0.17	0.35	6
	15	60	20	600	0.29	0.615	6
	25	20	10	400	0.1	0.204	5
	25	20	20	550	0.17	0.35	5
	25	60	10	500	0.15	0.429	5
	25	60	20	600	0.27	0.763	5
	35	20	10	400	0.09	0.227	5
	35	20	20	550	0.15	0.38	5
	35	60	10	500	0.14	0.475	5
	35	60	20	600	0.25	0.853	5
Slope = 3.5%							
	15	20	10	300	0.14	0.38	4
	15	20	20	500	0.19	0.52	4
	15	60	10	450	0.15	0.53	4
	15	60	20	550	0.26	0.93	4
	25	20	10	250	0.14	0.5	4
	25	20	20	450	0.18	0.69	4
	25	60	10	400	0.16	0.79	4
	25	60	20	550	0.24	1.27	4
	35	20	10	200	0.15	0.66	4
	35	20	20	400	0.18	0.82	4
	35	60	10	350	0.18	1.02	4
	35	60	20	500	0.25	1.35	4
Slope = 7%							
	15	20	10	200	0.23	0.6	5
	15	20	20	350	0.3	0.82	5
	15	60	10	300	0.23	0.819	5
	15	60	20	500	0.29	1.016	5
	25	20	10	150	0.27	0.85	5
	25	20	20	250	0.32	1.17	5
	25	60	10	200	0.28	1.27	5
	25	60	20	450	0.31	1.4	5
	35	20	10	100	0.28	1.14	5
	35	20	20	200	0.33	1.432	5
	35	60	10	150	0.33	1.69	5
	35	60	20	400	0.34	1.85	5

Table A-1 Summary of Finite Element Runs

TABLE A-2
SPEEDAL PROJECT TEST RUNS FOR ANISOTROPY AND NUMBER OF DRAINS

	Number of Drains	Slope	Trial Radius	Spacing	Trench Elevation	Free Head	k horiz.	k vert.	Total Flow	Man Free Surface Flow	Radius of Influence	Total Flow	Man Free Surface Flow
S8	4	3.5	100	25	60	10	0.2	0.02	0.1202	0.7863	350	0.08	0.6
	4	3.5	300	25	60	10	0.2	0.02	0.0533	0.4095			
	4	3.5	500	25	60	20	0.2	0.02	0.0492	0.347			
S9	4	3.5	200	25	60	10	0.6	0.2	0.3166	0.8284	350	0.23	0.63
	4	3.5	400	25	60	10	0.6	0.2	0.2185	0.5862			
	4	3.5	600	25	60	10	0.6	0.2	0.2026	0.4979			
S10	4	3.5	100	15	20	10	1.23	0.123	0.4001	0.2369	275	0.18	0.13
	4	3.5	300	15	20	10	1.23	0.123	0.1693	0.1253			
	4	3.5	500	15	20	10	1.23	0.123	0.1625	0.1024			
S11	4	3.5	100	15	20	10	0.2	0.02	0.0651	0.2369	275	0.03	0.13
	4	3.5	300	15	20	10	0.2	0.02	0.0276	0.1253			
	4	3.5	500	15	20	10	0.2	0.02	0.0265	0.1024			
S12	4	3.5	100	15	20	10	0.104	0.034	0.0639	0.4493	275	0.03	0.25
	4	3.5	300	15	20	10	0.104	0.034	0.0256	0.2425			
	4	3.5	500	15	20	10	0.104	0.034	0.0238	0.1981			
S13	4	3.5	100	15	20	10	0.6	0.2	0.3723	0.4531	250	0.17	0.27
	4	3.5	300	15	20	10	0.6	0.2	0.15	0.2447			
	4	3.5	500	15	20	10	0.6	0.2	0.1388	0.1999			
S15	3	3.5	100	15	20	10	0.2	0.2	0.3425	0.7908	325	0.13	0.37
	3	3.5	300	15	20	10	0.2	0.2	0.1344	0.389			
	3	3.5	500	15	20	10	0.2	0.2	0.1056	0.2925			
S16	3	0	300	25	20	20	0.2	0.2	0.2894	0.715	700	0.13	0.33
	3	0	500	25	20	20	0.2	0.2	0.1822	0.4537			
	3	0	700	25	20	20	0.2	0.2	0.1322	0.3321			
S17	3	7	100	35	20	20	0.2	0.2	0.5629	2.0473	275	0.29	1.25
	3	7	300	35	20	20	0.2	0.2	0.2713	1.1976			
	3	7	500	35	20	20	0.2	0.2	0.2653	0.9015			

TABLE A-3

Test	Slope	Trial Radius	Spacing	Trench Elevation	Free Head	k		q-total	Free Surface Max Influence	Radius of Total Influence	Total Flow	Max Free Surface	Dimensional Analysis Predict		
						horiz.	vertical						Radius of Total Influence	Max Free Surface	
S1	5	200	20	40	15	0.2	0.2	0.76405	1.173	450	0.23	0.8	327	0.26	0.96
	5	400	20	40	15	0.2	0.2	1.4207	2.1591	450	0.23	0.8	327	0.26	0.96
	5	600	20	40	15	0.2	0.2	0.90464	1.799	450	0.23	0.8	327	0.26	0.96
S2	3.5	400	25	40	20	0.2	0.2	1.59473	3.1004	610	0.205	0.86	493	0.26	0.96
	3.5	600	25	40	20	0.2	0.2	0.2005	0.8691	610	0.205	0.86	493	0.26	0.96
	3.5	800	25	40	20	0.2	0.2	0.3864	0.6093	610	0.205	0.86	493	0.26	0.96
S3	0	200	35	30	10	0.2	0.2	0.8212	1.2552	400	0.09	0.24	425	0.13	0.39
	0	400	35	30	10	0.2	0.2	0.5464	1.1507	400	0.09	0.24	425	0.13	0.39
	0	600	35	30	10	0.2	0.2	1.0432	2.0982	400	0.09	0.24	425	0.13	0.39
S5	3.5	200	15	50	10	0.2	0.2	0.2823	0.7822	400	0.16	0.54	410	0.18	0.7
	3.5	400	15	50	10	0.2	0.2	0.1564	0.5351	400	0.16	0.54	410	0.18	0.7
	3.5	600	15	50	10	0.2	0.2	0.128	0.4383	400	0.16	0.54	410	0.18	0.7
S6	7	100	25	30	10	0.2	0.2	0.3186	1.247	150	0.3	1.05	160	0.27	1.07
	7	300	25	30	10	0.2	0.2	0.2714	0.8359	150	0.3	1.05	160	0.27	1.07
	7	500	25	30	10	0.2	0.2	0.2675	0.743	150	0.3	1.05	160	0.27	1.07
S7	7	200	35	50	20	0.2	0.2	0.428	2.3121	350	.35	1.8	350	0.34	1.41
	7	400	35	50	20	0.2	0.2	0.3947	1.7108	350	.35	1.8	350	0.34	1.41
	7	600	35	50	20	0.2	0.2	0.3212	1.4832	350	.35	1.8	350	0.34	1.41

APPENDIX B
SAMPLE INPUT AND OUTPUT

APPENDIX B

SAMPLE INPUT DATA FILE

"A35521"
2,0.00001
90,29,0,30,20,6,4,0
1,-190,6.65,1
7,-190,22.65,1
11,-190,36.65,0
18,-114,3.99,1
24,-114,19.99,1
28,-114,32.99,0
35,-43.7,1.5295,1
41,-43.7,17.5295,1
45,-43.7,29.5295,0
52,-19,0.665,1
58,-19,16.665,1
62,-19,27.665,0
69,0,0,1
75,0,16,1
79,0,25,0
86,10,-0.35,1
92,10,16,1
96,10,20,0
103,11.5,-0.4025,1
109,11.5,16,1
113,11.5,20,0
120,16.5,-0.5775,1
126,16.5,16,1
130,16.5,22,0
137,23,-0.805,1
143,23,16,1
147,23,22,0
154,25,-0.875,1
160,25,16,1
164,25,22,0
171,31.5,-1.1025,1
177,31.5,16,1
181,31.5,22,0
188,36.5,-1.2775,1
194,36.5,16,1
198,36.5,20,0
205,38,-1.33,1
211,38,16,1
215,38,20,0
222,43,-1.505,1
228,43,16,1
232,43,22,0
239,49.5,-1.7325,1
245,49.5,16,1
249,49.5,22,0
256,51.5,-1.8025,1
262,51.5,16,1
266,51.5,22,0
273,58,-2.03,1
279,58,16,1
283,58,22,0
290,63,-2.205,1

296,63,16,1
 300,63,20,0
 307,64.5,-2.2575,1
 313,64.5,16,1
 317,64.5,20,0
 324,69.5,-2.4325,1
 330,69.5,16,1
 334,69.5,22,0
 341,76,-2.66,1
 347,76,16,1
 351,76,22,0
 358,78,-2.73,1
 364,78,16,1
 368,78,22,0
 375,84.5,-2.9575,1
 381,84.5,16,1
 385,84.5,22,0
 392,89.5,-3.1325,1
 398,89.5,16,1
 402,89.5,20,0
 409,91,-3.185,1
 415,91,16,1
 419,91,20,0
 426,101,-3.535,1
 432,101,15.65,1
 436,101,21.465,0
 443,120,-4.2,1
 449,120,14.985,1
 453,120,21.8,0
 460,144.7,-5.0645,1
 466,144.7,14.1205,1
 470,144.7,22.9355,0
 477,215,-7.525,1
 483,215,11.66,1
 487,215,21.475,0
 494,291,-10.185,1
 500,291,9,1
 504,291,19.815,0
 1,12,18,19,20,13,3,2,4,0.2,0.2,0
 18,29,35,36,37,30,20,19,4,0.2,0.2,0
 35,46,52,53,54,47,37,36,4,0.2,0.2,0
 52,63,69,70,71,64,54,53,4,0.2,0.2,0
 69,80,86,87,88,81,71,70,4,0.2,0.2,0
 86,97,103,104,105,98,88,87,4,0.2,0.2,0
 103,114,120,121,122,115,105,104,4,0.2,0.2,0
 120,131,137,138,139,132,122,121,4,0.2,0.2,0
 137,148,154,155,156,149,139,138,4,0.2,0.2,0
 154,165,171,172,173,166,156,155,4,0.2,0.2,0
 171,182,188,189,190,183,173,172,4,0.2,0.2,0
 188,199,205,206,207,200,190,189,4,0.2,0.2,0
 205,216,222,223,224,217,207,206,4,0.2,0.2,0
 222,233,239,240,241,234,224,223,4,0.2,0.2,0
 239,250,256,257,258,251,241,240,4,0.2,0.2,0
 256,267,273,274,275,268,258,257,4,0.2,0.2,0
 273,284,290,291,292,285,275,274,4,0.2,0.2,0

290,301,307,308,309,302,292,291,4,0.2,0.2,0
307,318,324,325,326,319,309,308,4,0.2,0.2,0
324,335,341,342,343,336,326,325,4,0.2,0.2,0
341,352,358,359,360,353,343,342,4,0.2,0.2,0
358,369,375,376,377,370,360,359,4,0.2,0.2,0
375,386,392,393,394,387,377,376,4,0.2,0.2,0
392,403,409,410,411,404,394,393,4,0.2,0.2,0
409,420,426,427,428,421,411,410,4,0.2,0.2,0
426,437,443,444,445,438,428,427,4,0.2,0.2,0
443,454,460,461,462,455,445,444,4,0.2,0.2,0
460,471,477,478,479,472,462,461,4,0.2,0.2,0
477,488,494,495,496,489,479,478,4,0.2,0.2,0
1,36.65,5,2,1
96,20,1,17,6
198,20,1,17,6
300,20,1,17,6
402,20,1,17,6
494,19.815,5,2,1
11,7,28,24,45,41,62,58,79,75,96,92,113,109,130,126
147,143,164,160,181,177,198,194,215,211,232,228,249,245,266,262
283,279,300,296,317,313,334,330,351,347,368,364,385,381,402,398
419,415,436,432,453,449,470,466,487,483,504,500
17,34,51,68,85,102,119,136,153,170,187,204,221,238,255,272
289,306,323,340,357,374,391,408,425,442,459,476,493
96,1,17
198,1,17
300,1,17
402,1,17
"End of Problem"
3,0.0001

SAMPLE OUTPUT

A35521

CE504CW

Userid: CE504CW
 File: CE504CW OUTPUT

F- .5902



1 .105
 2 .0349
 3 .0107
 4 .0026

USERID	CE504CW	
ORIGIN	RSCS	
DISTCODE	CE504CW	
SYSTEM	GITVM1	
SPOOLID	8001	
RECORDS	00001063	
FILE	CE504CW	OUTPUT
CREATED	07/03/89	23:02:08
PRINTED	07/03/89	23:02:23
CLASS	A	
FORMS	XD	
DEVICE	600	
SEQUENCE	769	

NPBC = 00 NEMMC = 23 NPBC = 0 NPBC = 30 TYCIV = 20 NPBC = 8 NEMFAC = 4 TYIME = 0

GENERATED NODAL POINT DATA AND (X)-(Y) COORDINATES

NODE 1	X=	-100.0000	Y=	5.8800
NODE 2	X=	-100.0000	Y=	11.8823
NODE 5	X=	-100.0000	Y=	17.3187
NODE 7	X=	-100.0000	Y=	22.8800
NODE 8	X=	-100.0000	Y=	28.8800
NODE 11	X=	-100.0000	Y=	38.8800
NODE 18	X=	-114.0000	Y=	3.8800
NODE 20	X=	-114.0000	Y=	8.3233
NODE 22	X=	-114.0000	Y=	12.8827
NODE 24	X=	-114.0000	Y=	18.8800
NODE 28	X=	-114.0000	Y=	28.8800
NODE 28	X=	-114.0000	Y=	32.8800
NODE 38	X=	-43.7000	Y=	1.8288
NODE 37	X=	-43.7000	Y=	6.8628
NODE 38	X=	-43.7000	Y=	12.1862
NODE 41	X=	-43.7000	Y=	17.8288
NODE 43	X=	-43.7000	Y=	23.8288
NODE 48	X=	-43.7000	Y=	28.8288
NODE 52	X=	-18.0000	Y=	8.8880
NODE 54	X=	-18.0000	Y=	8.8883
NODE 58	X=	-18.0000	Y=	11.2217
NODE 58	X=	-18.0000	Y=	18.8880
NODE 60	X=	-18.0000	Y=	22.1880
NODE 62	X=	-18.0000	Y=	27.8880
NODE 68	X=	0.0000	Y=	0.0000
NODE 71	X=	0.0000	Y=	8.2333
NODE 73	X=	0.0000	Y=	10.8887
NODE 75	X=	0.0000	Y=	18.0000
NODE 77	X=	0.0000	Y=	20.8500
NODE 79	X=	0.0000	Y=	28.0000
NODE 88	X=	10.0000	Y=	-2.3800
NODE 88	X=	10.0000	Y=	8.1000
NODE 90	X=	10.0000	Y=	10.8800
NODE 92	X=	10.0000	Y=	18.0000
NODE 94	X=	10.0000	Y=	18.0000
NODE 98	X=	10.0000	Y=	20.0000
NODE 103	X=	11.8000	Y=	-4.028
NODE 108	X=	11.8000	Y=	8.0880
NODE 107	X=	11.8000	Y=	10.8328
NODE 108	X=	11.8000	Y=	18.0000
NODE 111	X=	11.8000	Y=	18.0000
NODE 113	X=	11.8000	Y=	20.0000
NODE 120	X=	18.8000	Y=	-2.8778
NODE 122	X=	18.8000	Y=	4.8883
NODE 124	X=	18.8000	Y=	10.4722
NODE 128	X=	18.8000	Y=	18.0000
NODE 128	X=	18.8000	Y=	18.0000
NODE 130	X=	18.8000	Y=	22.0000
NODE 137	X=	23.0000	Y=	-4.8080
NODE 138	X=	23.0000	Y=	4.7887
NODE 141	X=	23.0000	Y=	10.3883
NODE 143	X=	23.0000	Y=	18.0000
NODE 148	X=	23.0000	Y=	18.0000
NODE 147	X=	23.0000	Y=	22.0000
NODE 184	X=	28.0000	Y=	-2.8780
NODE 188	X=	28.0000	Y=	4.7880

NODE 188	X=	28.0000	Y=	10.2780
NODE 180	X=	28.0000	Y=	18.0000
NODE 182	X=	28.0000	Y=	18.0000
NODE 184	X=	28.0000	Y=	22.0000
NODE 171	X=	31.8000	Y=	-1.1028
NODE 173	X=	31.8000	Y=	4.8883
NODE 178	X=	31.8000	Y=	10.2882
NODE 177	X=	31.8000	Y=	18.0000
NODE 178	X=	31.8000	Y=	18.0000
NODE 181	X=	31.8000	Y=	22.0000
NODE 188	X=	38.8000	Y=	-1.2778
NODE 190	X=	38.8000	Y=	4.4817
NODE 192	X=	38.8000	Y=	10.2408
NODE 194	X=	38.8000	Y=	18.0000
NODE 198	X=	38.8000	Y=	18.0000
NODE 198	X=	38.8000	Y=	20.0000
NODE 208	X=	38.8000	Y=	-1.2300
NODE 207	X=	38.8000	Y=	4.4887
NODE 208	X=	38.8000	Y=	10.2333
NODE 211	X=	38.8000	Y=	18.0000
NODE 213	X=	38.8000	Y=	18.0000
NODE 218	X=	38.8000	Y=	20.0000
NODE 222	X=	43.0000	Y=	-1.8080
NODE 224	X=	43.0000	Y=	4.3300
NODE 228	X=	43.0000	Y=	10.1880
NODE 228	X=	43.0000	Y=	18.0000
NODE 230	X=	43.0000	Y=	18.0000
NODE 232	X=	43.0000	Y=	22.0000
NODE 238	X=	48.8000	Y=	-1.7328
NODE 241	X=	48.8000	Y=	4.1783
NODE 243	X=	48.8000	Y=	10.0882
NODE 248	X=	48.8000	Y=	18.0000
NODE 247	X=	48.8000	Y=	18.0000
NODE 248	X=	48.8000	Y=	22.0000
NODE 288	X=	51.8000	Y=	-1.8028
NODE 288	X=	51.8000	Y=	6.1517
NODE 280	X=	51.8000	Y=	10.0888
NODE 282	X=	51.8000	Y=	18.0000
NODE 284	X=	51.8000	Y=	18.0000
NODE 288	X=	51.8000	Y=	22.0000
NODE 273	X=	58.0000	Y=	-2.0300
NODE 278	X=	58.0000	Y=	3.8800
NODE 277	X=	58.0000	Y=	8.8800
NODE 278	X=	58.0000	Y=	18.0000
NODE 281	X=	58.0000	Y=	18.0000
NODE 283	X=	58.0000	Y=	22.0000
NODE 280	X=	63.0000	Y=	-2.2080
NODE 282	X=	63.0000	Y=	2.8822
NODE 294	X=	63.0000	Y=	8.9317
NODE 288	X=	63.0000	Y=	18.0000
NODE 288	X=	63.0000	Y=	18.0000
NODE 300	X=	63.0000	Y=	20.0000
NODE 307	X=	64.8000	Y=	-2.2878
NODE 308	X=	64.8000	Y=	3.8283
NODE 313	X=	64.8000	Y=	8.8722
NODE 313	X=	64.8000	Y=	18.0000
NODE 318	X=	64.8000	Y=	18.0000
NODE 317	X=	64.8000	Y=	20.0000
NODE 324	X=	68.8000	Y=	-2.2328
NODE 328	X=	68.8000	Y=	3.7117
NODE 328	X=	68.8000	Y=	8.8888
NODE 330	X=	68.8000	Y=	18.0000
NODE 332	X=	68.8000	Y=	18.0000
NODE 334	X=	68.8000	Y=	22.0000
NODE 341	X=	76.0000	Y=	-2.8800

NODE 361	X:	76.0000	Y:	22.0000
NODE 362	X:	76.0000	Y:	-2.7200
NODE 363	X:	76.0000	Y:	3.5133
NODE 364	X:	76.0000	Y:	8.7857
NODE 365	X:	76.0000	Y:	16.0000
NODE 366	X:	76.0000	Y:	18.0000
NODE 367	X:	76.0000	Y:	22.0000
NODE 368	X:	44.5000	Y:	-2.8676
NODE 369	X:	44.5000	Y:	3.3617
NODE 370	X:	44.5000	Y:	8.8608
NODE 371	X:	44.5000	Y:	16.0000
NODE 372	X:	44.5000	Y:	18.0000
NODE 373	X:	44.5000	Y:	22.0000
NODE 374	X:	88.0000	Y:	-3.1226
NODE 375	X:	88.0000	Y:	3.2480
NODE 376	X:	88.0000	Y:	8.8226
NODE 377	X:	88.0000	Y:	16.0000
NODE 378	X:	88.0000	Y:	18.0000
NODE 379	X:	88.0000	Y:	20.0000
NODE 380	X:	88.0000	Y:	-3.1880
NODE 381	X:	81.0000	Y:	3.2100
NODE 382	X:	81.0000	Y:	8.8050
NODE 383	X:	81.0000	Y:	18.0000
NODE 384	X:	81.0000	Y:	18.0000
NODE 385	X:	81.0000	Y:	20.0000
NODE 386	X:	101.0000	Y:	-3.5350
NODE 387	X:	101.0000	Y:	2.8600
NODE 388	X:	101.0000	Y:	8.2650
NODE 389	X:	101.0000	Y:	15.8600
NODE 390	X:	101.0000	Y:	18.5675
NODE 391	X:	101.0000	Y:	21.4650
NODE 392	X:	120.0000	Y:	-4.2000
NODE 393	X:	120.0000	Y:	2.1850
NODE 394	X:	120.0000	Y:	8.5900
NODE 395	X:	120.0000	Y:	14.8850
NODE 396	X:	120.0000	Y:	18.3825
NODE 397	X:	120.0000	Y:	21.8800
NODE 398	X:	144.7000	Y:	-5.0448
NODE 399	X:	144.7000	Y:	1.3305
NODE 400	X:	144.7000	Y:	7.7214
NODE 401	X:	144.7000	Y:	14.1205
NODE 402	X:	144.7000	Y:	18.5280
NODE 403	X:	144.7000	Y:	22.9355
NODE 404	X:	216.0000	Y:	-7.5250
NODE 405	X:	216.0000	Y:	-1.1300
NODE 406	X:	216.0000	Y:	5.2650
NODE 407	X:	216.0000	Y:	11.5600
NODE 408	X:	216.0000	Y:	18.5675
NODE 409	X:	216.0000	Y:	21.4750
NODE 410	X:	281.0000	Y:	-10.1650
NODE 411	X:	281.0000	Y:	-3.7900
NODE 412	X:	281.0000	Y:	2.8050
NODE 413	X:	281.0000	Y:	8.0000
NODE 414	X:	281.0000	Y:	14.4075
NODE 415	X:	281.0000	Y:	18.8150

NUMBER OF NODAL POINTS: 504

NUMBER OF ELEMENTS: 145

ELE. NO. NODAL POINTS

1	1	12	18	19	20	13	3	2	.20000E+00	.20000E+00	0.
2	3	13	20	21	22	14	5	4	.20000E+00	.20000E+00	0.
2	5	14	22	23	24	15	7	6	.20000E+00	.20000E+00	0.
4	7	15	24	25	26	16	8	8	.20000E+00	.20000E+00	0.
5	8	16	26	27	28	17	11	10	.20000E+00	.20000E+00	0.
6	16	28	35	36	37	30	20	19	.20000E+00	.20000E+00	0.
7	20	30	37	38	39	31	22	21	.20000E+00	.20000E+00	0.
8	22	31	38	40	41	32	24	23	.20000E+00	.20000E+00	0.
9	24	32	41	42	43	33	26	25	.20000E+00	.20000E+00	0.
10	26	33	43	44	45	34	28	27	.20000E+00	.20000E+00	0.
11	35	46	52	53	54	47	37	36	.20000E+00	.20000E+00	0.
12	37	47	54	55	56	48	39	38	.20000E+00	.20000E+00	0.
13	39	48	56	57	58	49	41	40	.20000E+00	.20000E+00	0.
14	41	49	58	59	60	50	43	42	.20000E+00	.20000E+00	0.
15	43	50	60	61	62	51	45	44	.20000E+00	.20000E+00	0.
16	52	63	68	70	71	64	54	53	.20000E+00	.20000E+00	0.
17	54	64	71	72	73	65	56	55	.20000E+00	.20000E+00	0.
18	56	65	73	74	75	66	58	57	.20000E+00	.20000E+00	0.
19	58	66	75	76	77	67	60	59	.20000E+00	.20000E+00	0.
20	60	67	77	78	79	68	62	61	.20000E+00	.20000E+00	0.
21	68	80	86	87	88	81	71	70	.20000E+00	.20000E+00	0.
22	71	81	88	89	90	82	73	72	.20000E+00	.20000E+00	0.
23	73	82	90	91	92	83	75	74	.20000E+00	.20000E+00	0.
24	75	83	92	93	94	84	77	76	.20000E+00	.20000E+00	0.
25	77	84	94	95	96	85	79	78	.20000E+00	.20000E+00	0.
26	86	97	103	104	105	88	88	87	.20000E+00	.20000E+00	0.
27	88	98	105	106	107	89	90	89	.20000E+00	.20000E+00	0.
28	90	99	107	108	109	90	92	91	.20000E+00	.20000E+00	0.
29	92	100	109	110	111	101	94	93	.20000E+00	.20000E+00	0.
30	94	101	111	112	113	102	96	95	.20000E+00	.20000E+00	0.
31	103	114	120	121	122	115	105	104	.20000E+00	.20000E+00	0.
32	105	115	122	123	124	116	107	106	.20000E+00	.20000E+00	0.
33	107	116	124	125	126	117	109	108	.20000E+00	.20000E+00	0.
34	109	117	126	127	128	118	111	110	.20000E+00	.20000E+00	0.
35	111	118	128	129	130	119	113	112	.20000E+00	.20000E+00	0.
36	120	131	137	138	139	122	122	121	.20000E+00	.20000E+00	0.
37	122	132	139	140	141	123	124	123	.20000E+00	.20000E+00	0.
38	124	133	141	142	143	124	126	125	.20000E+00	.20000E+00	0.
39	126	134	143	144	145	125	128	127	.20000E+00	.20000E+00	0.
40	138	138	148	148	147	138	130	128	.20000E+00	.20000E+00	0.
41	137	148	164	165	166	148	139	138	.20000E+00	.20000E+00	0.
42	139	149	166	167	168	150	141	140	.20000E+00	.20000E+00	0.
43	141	150	168	169	170	151	143	142	.20000E+00	.20000E+00	0.
44	143	151	170	171	172	152	145	144	.20000E+00	.20000E+00	0.
45	145	152	172	173	174	153	147	146	.20000E+00	.20000E+00	0.
46	154	155	171	172	173	155	156	155	.20000E+00	.20000E+00	0.
47	156	156	173	174	175	157	158	157	.20000E+00	.20000E+00	0.
48	158	157	175	176	177	158	160	159	.20000E+00	.20000E+00	0.
49	160	158	177	178	179	159	162	161	.20000E+00	.20000E+00	0.
50	162	159	179	180	181	170	164	163	.20000E+00	.20000E+00	0.
51	171	162	188	188	190	163	173	172	.20000E+00	.20000E+00	0.
52	173	163	190	191	192	164	175	174	.20000E+00	.20000E+00	0.
53	175	164	192	193	194	165	177	176	.20000E+00	.20000E+00	0.
54	177	165	194	195	196	166	179	178	.20000E+00	.20000E+00	0.
55	179	166	196	197	198	167	181	180	.20000E+00	.20000E+00	0.
56	182	169	206	207	207	207	180	179	.20000E+00	.20000E+00	0.
57	180	200	207	208	208	201	182	181	.20000E+00	.20000E+00	0.
58	182	201	208	210	211	202	184	183	.20000E+00	.20000E+00	0.
59	184	202	211	212	213	203	186	185	.20000E+00	.20000E+00	0.
60	186	203	213	214	215	204	188	187	.20000E+00	.20000E+00	0.
61	206	216	222	223	224	217	207	206	.20000E+00	.20000E+00	0.
62	207	217	224	225	226	218	209	208	.20000E+00	.20000E+00	0.
63	209	218	226	227	228	219	211	210	.20000E+00	.20000E+00	0.
64	211	219	228	229	230	220	213	212	.20000E+00	.20000E+00	0.
65	213	220	230	231	232	221	215	214	.20000E+00	.20000E+00	0.
66	222	223	238	240	241	224	224	223	.20000E+00	.20000E+00	0.
67	224	224	241	242	243	225	226	225	.20000E+00	.20000E+00	0.

71	238	250	256	257	258	261	241	240	20000E+00	20000E+00	0
72	241	251	258	259	260	262	243	242	20000E+00	20000E+00	0
73	243	252	260	261	262	263	245	244	20000E+00	20000E+00	0
74	245	253	262	263	264	264	247	246	20000E+00	20000E+00	0
75	247	254	264	265	266	266	248	248	20000E+00	20000E+00	0
76	250	257	273	274	275	268	258	257	20000E+00	20000E+00	0
77	258	268	275	276	277	269	260	259	20000E+00	20000E+00	0
78	260	269	277	278	279	270	262	261	20000E+00	20000E+00	0
79	262	270	278	280	281	271	264	263	20000E+00	20000E+00	0
80	264	271	281	282	283	272	266	265	20000E+00	20000E+00	0
81	273	284	290	291	292	285	275	274	20000E+00	20000E+00	0
82	275	285	292	293	294	286	277	276	20000E+00	20000E+00	0
83	277	288	294	295	296	287	279	278	20000E+00	20000E+00	0
84	278	287	296	297	298	288	281	280	20000E+00	20000E+00	0
85	281	286	298	299	300	289	283	282	20000E+00	20000E+00	0
86	280	301	307	308	309	302	292	291	20000E+00	20000E+00	0
87	292	302	309	310	311	303	294	293	20000E+00	20000E+00	0
88	294	303	311	312	313	304	296	295	20000E+00	20000E+00	0
89	298	304	313	314	315	306	298	297	20000E+00	20000E+00	0
90	308	308	318	318	317	308	300	300	20000E+00	20000E+00	0
91	307	318	324	326	326	318	309	308	20000E+00	20000E+00	0
92	308	318	328	327	328	320	311	310	20000E+00	20000E+00	0
93	311	320	328	328	330	321	313	312	20000E+00	20000E+00	0
94	313	321	330	331	332	322	315	314	20000E+00	20000E+00	0
95	316	322	332	333	334	323	317	316	20000E+00	20000E+00	0
96	324	338	341	342	343	336	328	326	20000E+00	20000E+00	0
97	328	338	343	344	345	337	328	327	20000E+00	20000E+00	0
98	328	337	345	346	347	338	330	328	20000E+00	20000E+00	0
99	330	338	347	348	349	339	332	331	20000E+00	20000E+00	0
100	332	338	349	350	351	340	334	333	20000E+00	20000E+00	0
101	341	352	354	355	356	343	343	342	20000E+00	20000E+00	0
102	343	353	360	361	362	354	348	344	20000E+00	20000E+00	0
103	345	354	362	363	364	355	347	346	20000E+00	20000E+00	0
104	347	355	364	365	366	356	349	348	20000E+00	20000E+00	0
105	349	356	366	367	368	357	351	350	20000E+00	20000E+00	0
106	358	359	375	376	377	370	360	358	20000E+00	20000E+00	0
107	360	370	377	378	379	371	362	361	20000E+00	20000E+00	0
108	362	371	379	380	381	372	364	363	20000E+00	20000E+00	0
109	365	372	381	382	383	373	366	365	20000E+00	20000E+00	0
110	368	373	383	384	385	374	368	367	20000E+00	20000E+00	0
111	375	386	392	393	394	387	377	376	20000E+00	20000E+00	0
112	377	387	394	395	396	388	379	378	20000E+00	20000E+00	0
113	379	388	396	397	398	389	381	380	20000E+00	20000E+00	0
114	381	389	398	399	400	390	383	382	20000E+00	20000E+00	0
115	383	390	400	401	402	391	385	384	20000E+00	20000E+00	0
116	382	403	409	410	411	404	394	393	20000E+00	20000E+00	0
117	384	404	411	412	413	405	396	395	20000E+00	20000E+00	0
118	388	406	413	414	415	406	398	397	20000E+00	20000E+00	0
119	398	408	415	416	417	407	400	398	20000E+00	20000E+00	0
120	400	407	417	418	419	408	402	401	20000E+00	20000E+00	0
121	409	420	428	427	428	421	411	410	20000E+00	20000E+00	0
122	411	421	428	428	430	422	413	412	20000E+00	20000E+00	0
123	413	422	430	431	432	423	415	414	20000E+00	20000E+00	0
124	415	423	432	433	434	424	417	416	20000E+00	20000E+00	0
125	417	424	434	435	436	425	419	418	20000E+00	20000E+00	0
126	428	437	443	444	445	438	428	427	20000E+00	20000E+00	0
127	428	438	445	446	447	439	430	429	20000E+00	20000E+00	0
128	430	448	447	448	449	440	432	431	20000E+00	20000E+00	0
129	432	449	449	450	451	441	434	433	20000E+00	20000E+00	0
130	434	441	451	452	453	442	436	435	20000E+00	20000E+00	0
131	443	454	450	451	452	455	445	444	20000E+00	20000E+00	0
132	445	455	452	453	454	456	447	446	20000E+00	20000E+00	0
133	447	456	454	455	456	457	448	448	20000E+00	20000E+00	0

134	449	457	456	457	458	458	451	450	20000E+00	20000E+00	0
135	451	458	458	459	470	459	453	452	20000E+00	20000E+00	0
136	460	471	477	478	479	472	462	461	20000E+00	20000E+00	0
137	462	472	479	480	481	473	464	463	20000E+00	20000E+00	0
138	464	473	481	482	483	474	466	465	20000E+00	20000E+00	0
139	465	474	483	484	485	475	468	467	20000E+00	20000E+00	0
140	468	478	485	485	487	478	470	469	20000E+00	20000E+00	0
141	477	484	484	485	486	488	479	478	20000E+00	20000E+00	0
142	479	488	488	487	488	490	481	480	20000E+00	20000E+00	0
143	481	490	488	489	490	491	483	482	20000E+00	20000E+00	0
144	483	491	490	491	492	492	484	484	20000E+00	20000E+00	0
145	485	492	502	503	504	493	487	486	20000E+00	20000E+00	0

DIRICHLET BOUNDARY DATA
NODES RESPECTIVE DIRICHLET BOUNDARY CONDITIONS

1- 2	38.8500	38.8500
3- 4	38.8500	38.8500
5- 6	38.8500	38.8500
7- 8	38.8500	38.8500
9- 10	38.8500	38.8500
11- 10	38.8500	38.8500
11-102	20.0000	20.0000
113-102	20.0000	20.0000
198-204	20.0000	20.0000
218-204	20.0000	20.0000
306-308	20.0000	20.0000
317-308	20.0000	20.0000
402-408	20.0000	20.0000
418-408	20.0000	20.0000
484-498	19.8180	19.8180
488-497	19.8180	19.8180
488-499	19.8180	19.8180
500-501	19.8180	19.8180
502-503	19.8180	19.8180
504-503	19.8180	19.8180

NODAL POINTS ON FREE SURFACE

11	17	28	34	45	51	62	68	79	88	98	102	113	119	130	138	147	153	164	170
181	187	198	204	218	221	232	238	249	255	266	272	283	289	300	306	317	323	334	340
381	387	398	374	385	381	402	408	419	425	436	442	453	459	470	476	487	493	504	0

SEEPAGE FACE NODAL POINT DATA
CONSECUTIVE NODE NUMBERS ON THE SEEPAGE FACE

98-113
198-216
306-317
402-419

ITER = 1

NEW COORDINATES OF THE FREE SURFACE LINE

NODE+457	X :	218.0000	Y :	19.8889
NODE+470	X :	144.7000	Y :	19.9592
NODE+453	X :	120.0000	Y :	19.9848
NODE+438	X :	101.0000	Y :	20.0034
NODE+419	X :	81.0000	Y :	20.0000
NODE+402	X :	59.0000	Y :	20.0000
NODE+388	X :	84.0000	Y :	20.0261
NODE+368	X :	78.0000	Y :	20.0387

NODE 300	X = 83.0000	Y = 20.0000
NODE 283	X = 58.0000	Y = 20.0872
NODE 266	X = 51.5000	Y = 20.1388
NODE 249	X = 48.5000	Y = 20.1787
NODE 232	X = 43.0000	Y = 20.1834
NODE 215	X = 38.0000	Y = 20.0000
NODE 198	X = 38.5000	Y = 20.0000
NODE 181	X = 31.5000	Y = 20.3837
NODE 164	X = 28.0000	Y = 20.4887
NODE 147	X = 23.0000	Y = 20.5787
NODE 130	X = 18.5000	Y = 20.5218
NODE 113	X = 11.5000	Y = 20.0000
NODE 96	X = 10.0000	Y = 20.0000
NODE 79	X = 0.0000	Y = 22.0338
NODE 62	X = -18.0000	Y = 23.8888
NODE 45	X = -43.7000	Y = 28.6188
NODE 28	X = -114.0000	Y = 31.0307
NODE 11	X = -180.0000	Y = 38.8500

ITER = 2

NEW COORDINATES OF THE FREE SURFACE LINE

NODE 487	X = 215.0000	Y = 18.8888
NODE 470	X = 144.7000	Y = 18.8634
NODE 453	X = 120.0000	Y = 18.8910
NODE 436	X = 101.0000	Y = 20.0100
NODE 419	X = 81.0000	Y = 20.0000
NODE 402	X = 88.5000	Y = 20.0000
NODE 385	X = 84.5000	Y = 20.0323
NODE 368	X = 78.0000	Y = 20.0504
NODE 351	X = 76.0000	Y = 20.0538
NODE 334	X = 68.5000	Y = 20.0582
NODE 317	X = 64.5000	Y = 20.0000
NODE 300	X = 83.0000	Y = 20.0000
NODE 283	X = 58.0000	Y = 20.1108
NODE 266	X = 51.5000	Y = 20.1688
NODE 249	X = 48.5000	Y = 20.1780
NODE 232	X = 43.0000	Y = 20.1827
NODE 215	X = 38.0000	Y = 20.0000
NODE 198	X = 38.5000	Y = 20.0000
NODE 181	X = 31.5000	Y = 20.3813
NODE 164	X = 28.0000	Y = 20.5404
NODE 147	X = 23.0000	Y = 20.5787
NODE 130	X = 18.5000	Y = 20.5885
NODE 113	X = 11.5000	Y = 20.0000
NODE 96	X = 10.0000	Y = 20.0000
NODE 79	X = 0.0000	Y = 21.8330
NODE 62	X = -18.0000	Y = 23.7181
NODE 45	X = -43.7000	Y = 28.6308
NODE 28	X = -114.0000	Y = 31.3538
NODE 11	X = -180.0000	Y = 38.8500

ITER = 3

NEW COORDINATES OF THE FREE SURFACE LINE

NODE 487	X = 215.0000	Y = 18.8888
NODE 470	X = 144.7000	Y = 18.8638
NODE 453	X = 120.0000	Y = 18.8912
NODE 436	X = 101.0000	Y = 20.0102
NODE 419	X = 81.0000	Y = 20.0000
NODE 402	X = 88.5000	Y = 20.0000
NODE 385	X = 84.5000	Y = 20.0325
NODE 368	X = 78.0000	Y = 20.0505
NODE 351	X = 76.0000	Y = 20.0542
NODE 334	X = 68.5000	Y = 20.0585
NODE 317	X = 64.5000	Y = 20.0000
NODE 300	X = 83.0000	Y = 20.0000
NODE 283	X = 58.0000	Y = 20.1118
NODE 266	X = 51.5000	Y = 20.1877
NODE 249	X = 48.5000	Y = 20.1788
NODE 232	X = 43.0000	Y = 20.1834
NODE 215	X = 38.0000	Y = 20.0000
NODE 198	X = 38.5000	Y = 20.0000
NODE 181	X = 31.5000	Y = 20.3837
NODE 164	X = 28.0000	Y = 20.8432
NODE 147	X = 23.0000	Y = 20.8784
NODE 130	X = 18.5000	Y = 20.8902
NODE 113	X = 11.5000	Y = 20.0000
NODE 96	X = 10.0000	Y = 20.0000
NODE 79	X = 0.0000	Y = 21.8483
NODE 62	X = -18.0000	Y = 23.7817
NODE 45	X = -43.7000	Y = 28.8817
NODE 28	X = -114.0000	Y = 31.3882
NODE 11	X = -180.0000	Y = 38.8500

ITER = 4

NEW COORDINATES OF THE FREE SURFACE LINE

NODE 487	X = 215.0000	Y = 18.8888
NODE 470	X = 144.7000	Y = 18.8638
NODE 453	X = 120.0000	Y = 18.8912
NODE 436	X = 101.0000	Y = 20.0102
NODE 419	X = 81.0000	Y = 20.0000
NODE 402	X = 88.5000	Y = 20.0000
NODE 385	X = 84.5000	Y = 20.0325
NODE 368	X = 78.0000	Y = 20.0505
NODE 351	X = 76.0000	Y = 20.0542
NODE 334	X = 68.5000	Y = 20.0585
NODE 317	X = 64.5000	Y = 20.0000
NODE 300	X = 83.0000	Y = 20.0000
NODE 283	X = 58.0000	Y = 20.1118
NODE 266	X = 51.5000	Y = 20.1877
NODE 249	X = 48.5000	Y = 20.1788
NODE 232	X = 43.0000	Y = 20.1834
NODE 215	X = 38.0000	Y = 20.0000
NODE 198	X = 38.5000	Y = 20.0000
NODE 181	X = 31.5000	Y = 20.3837
NODE 164	X = 28.0000	Y = 20.8432
NODE 147	X = 23.0000	Y = 20.8783
NODE 130	X = 18.5000	Y = 20.8902
NODE 113	X = 11.5000	Y = 20.0000
NODE 96	X = 10.0000	Y = 20.0000
NODE 79	X = 0.0000	Y = 21.8500
NODE 62	X = -18.0000	Y = 23.7813
NODE 45	X = -43.7000	Y = 28.8813
NODE 28	X = -114.0000	Y = 31.3837
NODE 11	X = -180.0000	Y = 38.8500

F = .5902

CONVERGENCE CHECK ERROR = .3734E-06

ONODE X COORDINATE Y COORDINATE V-POTENTIAL X-VELOCITY Y-VELOCITY TOTAL VELO. PRES. COEF.

5	-180.0000	17.3187	38.8800	-1388E-01	1088E-03	1388E-01
6	-180.0000	18.8833	38.8800	-1348E-01	7180E-14	1348E-01
7	-180.0000	22.8800	38.8800	-1340E-01	1141E-03	1340E-01
8	-180.0000	28.1800	38.8800	-1330E-01	0	1330E-01
9	-180.0000	28.8800	38.8800	-1318E-01	1388E-03	1318E-01
10	-180.0000	33.1800	38.8800	-1307E-01	1084E-13	1307E-01
11	-180.0000	38.8800	38.8800	-1293E-01	1888E-03	1293E-01
12	-182.0000	6.3200	33.8840	-1419E-01	4429E-03	1420E-01
13	-182.0000	10.8833	34.0034	-1415E-01	8018E-03	1418E-01
14	-182.0000	18.8887	34.0208	-1411E-01	8898E-03	1412E-01
15	-182.0000	21.3200	34.0383	-1408E-01	8428E-03	1408E-01
16	-182.0000	27.8858	34.0558	-1397E-01	7488E-03	1397E-01
17	-182.0000	34.0018	34.0733	-1388E-01	8808E-03	1388E-01
18	-114.0000	3.8800	31.2518	-1487E-01	8174E-03	1488E-01
19	-114.0000	8.8887	31.2640	-1488E-01	8174E-03	1488E-01
20	-114.0000	8.3233	31.2483	-1488E-01	4387E-03	1488E-01
21	-114.0000	11.8800	31.2738	-1488E-01	8440E-03	1470E-01
22	-114.0000	14.8887	31.2828	-1488E-01	7800E-03	1471E-01
23	-114.0000	17.3233	31.2822	-1488E-01	7871E-03	1471E-01
24	-114.0000	18.8800	31.3027	-1470E-01	8728E-03	1472E-01
25	-114.0000	22.8308	31.3144	-1471E-01	8488E-03	1473E-01
26	-114.0000	28.8718	31.3288	-1471E-01	8841E-03	1474E-01
27	-114.0000	28.8124	31.3387	-1472E-01	8278E-03	1478E-01
28	-114.0000	31.3832	31.3432	-1472E-01	1082E-02	1478E-01
29	-78.8800	2.7888	28.8784	-1888E-01	8418E-03	1888E-01
30	-78.8800	8.0831	28.8928	-1883E-01	8788E-03	1888E-01
31	-78.8800	13.4284	28.8131	-1882E-01	8172E-03	1884E-01
32	-78.8800	18.7888	28.8388	-1882E-01	8833E-03	1882E-01
33	-78.8800	23.8830	28.8821	-1887E-01	1078E-02	1880E-01
34	-78.8800	28.8082	28.8808	-1884E-01	1200E-02	1888E-01
35	-43.7000	1.8288	25.7438	-1888E-01	8828E-03	1880E-01
36	-43.7000	4.1888	25.7830	-1888E-01	8833E-03	1880E-01
37	-43.7000	8.8824	25.7812	-1888E-01	7821E-03	1888E-01
38	-43.7000	8.5288	25.7718	-1888E-01	8288E-03	1888E-01
39	-43.7000	12.1882	25.7834	-1888E-01	8212E-03	1887E-01
40	-43.7000	14.8824	25.7880	-1883E-01	8820E-03	1888E-01
41	-43.7000	17.5288	25.8088	-1881E-01	1081E-02	1888E-01
42	-43.7000	18.8118	25.8213	-1880E-01	1134E-02	1884E-01
43	-43.7000	21.8844	25.8334	-1888E-01	1204E-02	1883E-01
44	-43.7000	23.7788	25.8488	-1847E-01	1227E-02	1882E-01
45	-43.7000	28.8893	25.8890	-1844E-01	1327E-02	1848E-01
46	-31.3800	1.0873	24.7037	-1701E-01	8808E-03	1702E-01
47	-31.3800	6.4308	24.7218	-1700E-01	7822E-03	1702E-01
48	-31.3800	11.7838	24.7447	-1701E-01	8282E-03	1703E-01
49	-31.3800	17.0873	24.7728	-1700E-01	1133E-02	1704E-01
50	-31.3800	20.8513	24.7888	-1887E-01	1274E-02	1702E-01
51	-31.3800	24.8083	24.8228	-1888E-01	1422E-02	1701E-01
52	-18.0000	8.8800	23.8408	-1780E-01	8807E-03	1781E-01
53	-18.0000	3.3317	23.8488	-1788E-01	8888E-03	1781E-01
54	-18.0000	8.8883	23.8882	-1780E-01	7788E-03	1781E-01
55	-18.0000	8.8880	23.8880	-1788E-01	7778E-03	1780E-01
56	-18.0000	11.3317	23.8780	-1747E-01	8828E-03	1780E-01
57	-18.0000	13.8883	23.8814	-1748E-01	8814E-03	1748E-01
58	-18.0000	18.8880	23.7084	-1742E-01	1227E-02	1748E-01
59	-18.0000	18.4388	23.7188	-1741E-01	1300E-02	1748E-01
60	-18.0000	20.2081	23.7288	-1740E-01	1428E-02	1748E-01
61	-18.0000	21.8787	23.7388	-1728E-01	1272E-02	1734E-01
62	-18.0000	23.7813	23.7810	-1718E-01	1828E-02	1723E-01
63	-8.8000	3.328	22.8148	-1704E-01	8818E-03	1708E-01
64	-8.8000	8.8888	22.8278	-1730E-01	2818E-03	1730E-01
65	-8.8000	10.8882	22.8382	-1788E-01	2181E-03	1788E-01
66	-8.8000	18.3228	22.8884	-1841E-01	7230E-03	1842E-01
67	-8.8000	18.8818	22.8720	-1883E-01	1072E-02	1888E-01

68	-8.8000	22.8807	22.8898	-1881E-01	1823E-02	1888E-01
69	0.0000	0.0000	22.0187	-1828E-01	8472E-03	1828E-01
70	0.0000	2.8887	22.0188	-1848E-01	1082E-03	1848E-01
71	0.0000	8.3333	22.0138	-1882E-01	7038E-03	1883E-01
72	0.0000	8.0000	22.0008	-1784E-01	1178E-02	1788E-01
73	0.0000	10.8887	21.8824	-1844E-01	1387E-02	1848E-01
74	0.0000	13.3333	21.8830	-1883E-01	1084E-02	1888E-01
75	0.0000	18.0000	21.8843	-2084E-01	2748E-03	2084E-01
76	0.0000	17.4878	21.8830	-2088E-01	8083E-03	2088E-01
77	0.0000	18.8780	21.8818	-2018E-01	3188E-02	2040E-01
78	0.0000	20.4828	21.8883	-1723E-01	8083E-03	1728E-01
79	0.0000	21.8800	21.8488	-1308E-01	4787E-02	1388E-01
80	8.0000	-1.780	21.8388	-1408E-01	8103E-03	1408E-01
81	8.0000	8.2187	21.8218	-1488E-01	1718E-02	1478E-01
82	8.0000	18.8883	21.8404	-1888E-01	4333E-03	1701E-01
83	8.0000	18.0000	21.8882	-2228E-01	7387E-02	2347E-01
84	8.0000	18.4878	21.8408	-2877E-01	8311E-02	2884E-01
85	8.0000	20.8780	21.4088	-3878E-01	1233E-02	3878E-01
86	10.0000	38.000	21.3117	-1180E-01	4088E-03	1181E-01
87	10.0000	2.3780	21.3081	-1208E-01	1002E-02	1208E-01
88	10.0000	8.1000	21.2843	-1222E-01	2480E-02	1247E-01
89	10.0000	7.8280	21.2388	-1282E-01	4487E-02	1338E-01
90	10.0000	10.8800	21.1828	-1318E-01	8808E-02	1487E-01
91	10.0000	13.2780	21.0438	-1477E-01	1182E-01	1891E-01
92	10.0000	18.0000	20.8408	-1824E-01	1848E-01	2803E-01
93	10.0000	17.0000	20.7228	-2188E-01	2788E-01	3830E-01
94	10.0000	18.0000	20.8840	-2712E-01	3381E-01	4318E-01
95	10.0000	18.0000	20.3388	-3818E-01	8840E-01	8700E-01
96	10.0000	20.0000	20.8088	-4088E-01	8203E-01	7413E-01
97	10.7800	-3.783	21.2880	-1148E-01	4440E-03	1148E-01
98	10.7800	8.0828	21.2800	-1188E-01	4718E-03	1188E-01
99	10.7800	10.8413	21.1188	-1183E-01	8238E-02	1381E-01
100	10.7800	18.0000	20.7802	-1148E-01	1800E-01	2218E-01
101	10.7800	18.0000	20.8182	-8238E-02	3824E-01	3821E-01
102	10.7800	20.8000	20.0000	-1218E-01	4788E-01	8788E-01
103	11.8000	-4.028	21.2288	-1108E-01	4083E-03	1108E-01
104	11.8000	2.3313	21.2218	-1118E-01	1037E-02	1120E-01
105	11.8000	8.0880	21.1873	-1123E-01	2488E-02	1180E-01
106	11.8000	7.7888	21.1804	-1118E-01	4823E-02	1208E-01
107	11.8000	10.8328	21.0738	-1120E-01	8818E-02	1288E-01
108	11.8000	13.2883	20.8838	-9878E-02	1188E-01	1538E-01
109	11.8000	18.0000	20.7848	-8884E-02	1838E-01	1884E-01
110	11.8000	17.0000	20.8480	-2841E-02	2830E-01	2844E-01
111	11.8000	18.0000	20.8018	3788E-02	3118E-01	3137E-01
112	11.8000	18.0000	20.3048	1728E-01	8018E-01	8303E-01
113	11.8000	20.0000	20.0000	3088E-01	8818E-01	8888E-01
114	14.0000	-4.800	21.0848	-8883E-02	3804E-03	8870E-02
115	14.0000	8.0887	21.0871	-8782E-02	2383E-02	1007E-01
116	14.0000	10.8033	20.8828	-8722E-02	8898E-02	1088E-01
117	14.0000	18.0000	20.7088	-2802E-02	1228E-01	1288E-01
118	14.0000	18.1478	20.8477	-1840E-02	1880E-01	1880E-01
119	18.0000	20.8881	20.8287	2884E-01	2834E-02	3811E-01
120	18.0000	-8.778	20.8788	-8882E-02	3018E-03	8878E-02
121	18.0000	2.1884	20.8748	-8830E-02	8004E-03	8877E-02
122	18.0000	4.8833	20.8838	-8480E-02	2138E-03	8728E-02
123	18.0000	7.7113	20.8181	-7783E-02	3883E-02	8840E-02
124	18.0000	10.4742	20.8874	-8844E-02	4881E-02	8888E-02
125	18.0000	13.2371	20.7788	-4383E-02	8888E-02	7420E-02
126	18.0000	18.0000	20.8818	-1018E-02	4214E-02	4287E-02
127	18.0000	17.1478	20.8878	8224E-03	8112E-02	8178E-02
128	18.0000	18.2881	20.8333	2082E-02	2888E-02	3380E-02
129	18.0000	18.4428	20.8087	1332E-03	3781E-02	3783E-02
130	18.8000	20.8802	20.8801	-3381E-02	2770E-02	4371E-02
131	18.7800	-8.813	20.8477	-7488E-02	2803E-02	7481E-02
132	18.7800	4.8728	20.8278	-7240E-02	1708E-02	7438E-02

138	23 0000	4 7887	20 7888	- 8277E-02	- 3597E-02	6384E-02
140	23 0000	7 8376	20 8370	- 8408E-02	- 1318E-02	8384E-02
141	23 0000	10 3883	20 8889	- 8311E-02	- 2388E-02	8107E-02
142	23 0000	13 1882	20 8331	- 4681E-02	- 2282E-02	8628E-02
143	23 0000	18 0000	20 8027	- 3888E-02	- 1888E-02	8131E-02
144	23 0000	17 1444	20 8931	- 3888E-02	- 1478E-02	4303E-02
145	23 0000	18 2882	20 8888	- 3813E-02	- 8318E-03	3888E-02
146	23 0000	18 4337	20 8810	- 3500E-02	- 6882E-03	3882E-02
147	23 0000	20 8783	20 8783	- 3500E-02	- 1274E-03	3502E-02
148	24 0000	- 8400	20 7638	- 8188E-02	- 2071E-03	8188E-02
149	24 0000	4 7733	20 8884	- 8002E-02	- 1240E-02	8128E-02
150	24 0000	10 3887	20 8408	- 8270E-02	- 2246E-02	8728E-02
151	24 0000	18 0000	20 8827	- 4180E-02	- 1738E-02	4800E-02
152	24 0000	18 2804	20 8878	- 3788E-02	- 8328E-03	3810E-02
153	24 0000	20 8808	20 8824	- 3814E-02	- 8080E-05	3814E-02
154	28 0000	- 8780	20 8734	- 8810E-02	- 1812E-03	8812E-02
155	28 0000	1 8375	20 8718	- 8872E-02	- 4728E-03	8881E-02
156	28 0000	4 7800	20 8801	- 8778E-02	- 1148E-02	8880E-02
157	28 0000	7 8828	20 8403	- 8818E-02	- 1623E-02	8782E-02
158	28 0000	10 3780	20 8148	- 8204E-02	- 2038E-02	8888E-02
159	28 0000	13 1878	20 8881	- 4808E-02	- 1884E-02	8188E-02
160	28 0000	18 0000	20 8812	- 4432E-02	- 1820E-02	4888E-02
161	28 0000	17 1387	20 8838	- 4288E-02	- 1188E-02	4484E-02
162	28 0000	18 2718	20 8478	- 4732E-02	- 7877E-03	4243E-02
163	28 0000	18 4074	20 8444	- 4048E-02	- 4217E-03	4071E-02
164	28 0000	20 8432	20 8431	- 3882E-02	- 1278E-03	3888E-02
165	28 2800	- 8888	20 8834	- 8187E-02	- 1788E-03	8188E-02
166	28 2800	4 8742	20 8720	- 8144E-02	- 1000E-02	8241E-02
167	28 2800	10 3371	20 8319	- 4877E-02	- 1888E-02	8312E-02
168	28 2800	18 0000	20 4432	- 8187E-02	- 1882E-02	8388E-02
169	28 2800	18 2287	20 4708	- 8301E-02	- 8748E-03	8372E-02
170	28 2800	20 4638	20 4877	- 8518E-02	- 4883E-04	8820E-02
171	31 8000	- 1 1028	20 8048	- 4518E-02	- 1807E-03	4820E-02
172	31 8000	1 7478	20 8030	- 4534E-02	- 3837E-03	4880E-02
173	31 8000	4 8883	20 8937	- 4540E-02	- 8192E-03	4833E-02
174	31 8000	7 4488	20 8788	- 4883E-02	- 1413E-02	4788E-02
175	31 8000	10 2982	20 4834	- 4877E-02	- 1882E-02	8048E-02
176	31 8000	13 1486	20 4241	- 8208E-02	- 2111E-02	8617E-02
177	31 8000	18 0000	20 3833	- 8047E-02	- 2018E-02	8374E-02
178	31 8000	17 0808	20 3828	- 8848E-02	- 1877E-02	8734E-02
179	31 8000	18 1819	20 3781	- 8848E-02	- 7230E-03	8884E-02
180	31 8000	18 2728	20 3892	- 8084E-02	- 1131E-02	8188E-02
181	31 8000	20 3837	20 3837	- 4788E-02	- 1338E-02	4871E-02
182	34 0000	- 1 1800	20 4810	- 4082E-02	- 1428E-03	4084E-02
183	34 0000	4 8400	20 4400	- 4080E-02	- 8024E-03	4178E-02
184	34 0000	10 2700	20 3880	- 4181E-02	- 2028E-02	4148E-02
185	34 0000	18 0000	20 3173	- 8888E-02	- 3708E-02	8788E-02
186	34 0000	18 0908	20 2788	- 8183E-02	- 4884E-02	8431E-02
187	34 0000	20 1818	20 2873	- 1482E-01	- 8874E-03	1488E-01
188	38 8000	- 1 2778	20 4030	- 3817E-02	- 1337E-02	3818E-02
189	38 8000	1 8021	20 4012	- 3824E-02	- 3733E-03	3843E-02
190	38 8000	4 4817	20 3822	- 3811E-02	- 8708E-03	3714E-02
191	38 8000	7 3813	20 3788	- 3882E-02	- 1483E-02	3877E-02
192	38 8000	10 2408	20 3488	- 3827E-02	- 2047E-02	4077E-02
193	38 8000	13 1204	20 3118	- 3788E-02	- 3428E-02	4083E-02
194	38 8000	18 0000	20 2808	- 4430E-02	- 8278E-02	8881E-02
195	38 8000	17 0000	20 2180	- 8488E-02	- 7811E-02	8288E-02
196	38 8000	18 0000	20 1787	- 7182E-02	- 8481E-02	1188E-01
197	38 8000	18 0000	20 1121	- 1078E-01	- 1787E-01	2080E-01
198	38 8000	20 0000	20 0000	- 1408E-01	- 2181E-01	2808E-01
199	37 2800	- 1 3038	20 3888	- 3488E-02	- 1278E-03	3482E-02

200	37 2800	4 4842	20 3790	- 3473E-02	- 8810E-03	3878E-02
201	37 2800	10 2321	20 3388	- 3331E-02	- 1848E-02	3880E-02
202	37 2800	18 0000	20 2371	- 3181E-02	- 8301E-02	8187E-02
203	37 2800	18 0000	20 1888	- 2813E-02	- 1001E-01	1042E-01
204	37 2800	20 0000	20 0000	- 1384E-12	- 2188E-01	2188E-01
205	38 0000	- 1 3300	20 3788	- 3388E-02	- 1184E-03	3370E-02
206	38 0000	1 8883	20 3781	- 3382E-02	- 3817E-03	3381E-02
207	38 0000	4 4487	20 3883	- 3341E-02	- 8388E-03	3448E-02
208	38 0000	7 3380	20 3800	- 3238E-02	- 1441E-02	3842E-02
209	38 0000	10 2333	20 3247	- 3140E-02	- 1888E-02	3721E-02
210	38 0000	13 1117	20 2873	- 2741E-02	- 3378E-02	4348E-02
211	38 0000	18 0000	20 2272	- 1802E-02	- 8223E-02	8888E-02
212	38 0000	18 0000	20 1888	- 7801E-03	- 7374E-03	8288E-02
213	38 0000	18 0000	20 1838	- 8828E-03	- 8218E-02	8288E-02
214	38 0000	18 0000	20 0843	- 4880E-02	- 1838E-01	1817E-01
215	38 0000	20 0000	20 0000	- 8122E-02	- 1840E-01	2084E-01
216	40 8000	- 1 4178	20 3371	- 2884E-02	- 1068E-03	2888E-02
217	40 8000	4 3883	20 3278	- 2820E-02	- 7832E-03	3018E-02
218	40 8000	10 1842	20 2804	- 2800E-02	- 1801E-02	3081E-02
219	40 8000	18 0000	20 2144	- 8338E-03	- 3848E-02	3801E-02
220	40 8000	18 0488	20 1781	- 1784E-02	- 4438E-02	4778E-02
221	40 8000	20 0817	20 1837	- 7388E-02	- 1414E-02	7823E-02
222	43 0000	- 1 8080	20 3021	- 2828E-02	- 8117E-04	2830E-02
223	43 0000	1 4128	20 3007	- 2802E-02	- 2847E-03	2818E-02
224	43 0000	4 3300	20 2938	- 2838E-02	- 8881E-03	2828E-02
225	43 0000	7 2478	20 2812	- 2318E-02	- 1084E-02	2881E-02
226	43 0000	10 1880	20 2827	- 2023E-02	- 1484E-02	2808E-02
227	43 0000	13 0828	20 2388	- 1272E-02	- 1780E-02	2171E-02
228	43 0000	18 0000	20 2114	- 2371E-03	- 1787E-02	1803E-02
229	43 0000	18 0488	20 2024	- 2788E-03	- 1874E-02	1487E-02
230	43 0000	18 0817	20 1804	- 8787E-03	- 7827E-03	8821E-03
231	43 0000	18 1378	20 1892	- 1803E-04	- 1188E-02	1188E-02
232	43 0000	20 1834	20 1834	- 8882E-03	- 8881E-03	1248E-02
233	48 2800	- 1 8188	20 2824	- 2271E-02	- 7838E-04	2273E-02
234	48 2800	4 2842	20 2884	- 2187E-02	- 8313E-03	2281E-02
235	48 2800	10 1271	20 2328	- 1788E-02	- 1070E-02	2083E-02
236	48 2800	18 0000	20 2017	- 7884E-03	- 1013E-02	1281E-02
237	48 2800	18 0808	20 1938	- 4803E-03	- 8488E-03	7838E-03
238	48 2800	20 1812	20 1812	- 1403E-03	- 8227E-04	1878E-03
239	48 8000	- 1 7328	20 2282	- 1888E-02	- 7278E-04	1880E-02
240	48 8000	1 2228	20 2274	- 1837E-02	- 1717E-03	1848E-02
241	48 8000	4 1783	20 2231	- 1888E-02	- 4114E-03	1838E-02
242	48 8000	7 1338	20 2188	- 1784E-02	- 8880E-03	1888E-02
243	48 8000	10 0 92	20 2088	- 1810E-02	- 7408E-03	1772E-02
244	48 8000	13 0448	20 1848	- 1380E-02	- 8887E-02	1882E-02
245	48 8000	18 0000	20 1884	- 1178E-02	- 8228E-03	1284E-02
246	48 8000	17 0447	20 1884	- 1138E-02	- 4200E-03	1210E-02
247	48 8000	18 0884	20 1810	- 1100E-02	- 2817E-03	1130E-02
248	48 8000	18 1382	20 1787	- 1108E-02	- 2048E-03	1128E-02
249	48 8000	20 1788	20 1788	- 1188E-02	- 3088E-04	1188E-02
250	50 8000	- 1 7878	20 2188	- 1881E-02	- 4297E-04	1888E-02
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252	50 8000	10 0778	20 1878	- 1884E-02	- 8882E-03	1743E-02
253	50 8000	18 0000	20 1783	- 1288E-02	- 8088E-03	1383E-02
254	50 8000	18 0887	20 1783	- 1148E-02	- 2744E-03	1217E-02
255	50 8000	20 1733	20 1738	- 1148E-02	- 1832E-04	1118E-02
256	51 8000	- 1 8028	20 2083	- 1808E-02	- 8818E-04	1807E-02
257	51 8000	1 1848	20 2087	- 1793E-02	- 1482E-03	1788E-02
258	51 8000	4 1317	20 2048	- 1762E-02	- 3888E-03	1788E-02
259	51 8000	7 0888	20 1984	- 1880E-02	- 8087E-03	1788E-02
260	51 8000	10 0888	20 1889	- 1881E-02	- 8348E-03	1704E-02
261	51 8000	13 0328	20 1807	- 1488E-02	- 8778E-03	1878E-02
262	51 8000	18 0000	20 1727	- 1388E-02	- 4477E-03	1430E-02
263	51 8000	17 0418	20 1707	- 1327E-02	- 3438E-03	1371E-02
264	51 8000	18 0838	20 1882	- 1287E-02	- 2280E-03	1317E-02
265	51 8000	18 1288	20 1881	- 1288E-02	- 1388E-03	1278E-02

271	84 7800	18 0000	20 1488	- 1892E-02	- 4789E-03	1681E-02
272	84 7800	20 1388	20 1441	- 1728E-02	- 1927E-04	1728E-02
273	88 0000	- 2 0300	20 1870	- 1393E-02	- 4986E-04	1394E-02
274	88 0000	8 8780	20 1870	- 1397E-02	- 1187E-02	1402E-02
275	88 0000	3 8800	20 1840	- 1388E-02	- 2887E-03	1428E-02
276	88 0000	8 8810	20 1840	- 1404E-02	- 4383E-03	1471E-02
277	88 0000	8 8900	20 1848	- 1426E-02	- 5884E-03	1543E-02
278	88 0000	12 8980	20 1312	- 1892E-02	- 8890E-03	1723E-02
279	88 0000	18 0000	20 1210	- 1884E-02	- 8324E-03	1888E-02
280	88 0000	17 0278	20 1178	- 2014E-02	- 8088E-03	2078E-02
281	88 0000	18 0888	20 1188	- 2103E-02	- 2663E-03	2120E-02
282	88 0000	18 0837	20 1138	- 1886E-02	- 4099E-03	1830E-02
283	88 0000	20 1118	20 1118	- 1884E-02	- 3436E-03	1891E-02
284	80 8000	- 2 1178	20 1410	- 1280E-02	- 4428E-04	1281E-02
285	80 8000	3 8217	20 1374	- 1262E-02	- 2772E-03	1292E-02
286	80 8000	8 8808	20 1238	- 1283E-02	- 8202E-03	1426E-02
287	80 8000	18 0000	20 0978	- 1783E-02	- 1183E-02	2088E-02
288	80 8000	18 0278	20 0888	- 2488E-02	- 1483E-02	2887E-02
289	80 8000	20 0888	20 0814	- 4474E-02	- 8082E-03	4503E-02
290	83 0000	- 2 2080	20 1280	- 1130E-02	- 4178E-04	1131E-02
291	83 0000	8 8282	20 1288	- 1131E-02	- 1132E-03	1137E-02
292	83 0000	3 8833	20 1228	- 1128E-02	- 2848E-03	1188E-02
293	83 0000	8 8978	20 1172	- 1113E-02	- 4807E-03	1201E-02
294	83 0000	8 8317	20 1088	- 1091E-02	- 8188E-03	1284E-02
295	83 0000	12 8888	20 0988	- 1187E-02	- 1049E-02	1888E-02
296	83 0000	18 0000	20 0772	- 1877E-02	- 1830E-02	2178E-02
297	83 0000	17 0000	20 0873	- 1871E-02	- 1871E-02	2881E-02
298	83 0000	8 0000	20 0840	- 2181E-02	- 2823E-02	3883E-02
299	83 0000	18 0000	20 0343	- 3224E-02	- 6388E-03	6286E-02
300	83 0000	20 0000	20 0000	- 4189E-02	- 8793E-02	7881E-02
301	83 7800	- 2 2313	20 1218	- 1083E-02	- 3889E-04	1084E-02
302	83 7800	3 8488	20 1188	- 1086E-02	- 2888E-03	1116E-02
303	83 7800	8 8228	20 1080	- 1038E-02	- 8004E-03	1197E-02
304	83 7800	18 0000	20 0730	- 8888E-03	- 1833E-02	1888E-02
305	83 7800	18 0000	20 0480	- 8877E-03	- 3088E-02	3211E-02
306	83 7800	20 0000	20 0000	- 1384E-12	- 8702E-02	8702E-02
307	84 8000	- 2 2878	20 1178	- 1088E-02	- 3720E-04	1088E-02
308	84 8000	7 8844	20 1173	- 1088E-02	- 1082E-03	1081E-02
309	84 8000	3 8283	20 1148	- 1048E-02	- 2848E-03	1078E-02
310	84 8000	8 8713	20 1083	- 1013E-02	- 4388E-03	1103E-02
311	84 8000	8 8142	20 1012	- 9828E-03	- 8023E-03	1182E-02
312	84 8000	12 8871	20 0893	- 8888E-03	- 1028E-02	1338E-02
313	84 8000	18 0000	20 0889	- 8870E-03	- 1808E-02	1712E-02
314	84 8000	17 0000	20 0802	- 2388E-03	- 2881E-02	2278E-02
315	84 8000	18 0000	20 0473	- 2870E-03	- 2888E-02	2882E-02
316	84 8000	18 0000	20 0280	- 1808E-02	- 4721E-02	4888E-02
317	84 8000	20 0000	20 0000	- 2788E-02	- 5880E-02	6318E-02
318	87 0000	- 2 3480	20 1083	- 8487E-03	- 3387E-04	8473E-03
319	87 0000	3 7700	20 1023	- 8280E-03	- 2318E-03	8548E-03
320	87 0000	8 8880	20 0804	- 7880E-03	- 8488E-03	8488E-03
321	87 0000	18 0000	20 0889	- 2028E-03	- 1091E-02	1110E-02
322	87 0000	18 0141	20 0848	- 8288E-03	- 1381E-02	1489E-02
323	87 0000	20 0282	20 0804	- 2283E-02	- 4888E-03	2318E-02
324	88 8000	- 2 4328	20 0841	- 8440E-03	- 2832E-04	8448E-03
325	88 8000	8 8388	20 0837	- 8388E-03	- 8888E-04	8400E-03
326	88 8000	3 7117	20 0818	- 8183E-03	- 2029E-03	8411E-03
327	88 8000	8 7838	20 0874	- 7483E-03	- 3283E-03	8180E-03
328	88 8000	8 8884	20 0818	- 8880E-03	- 4888E-03	8003E-03
329	88 8000	12 8278	20 0738	- 4202E-03	- 8421E-03	8889E-03
330	88 8000	18 0000	20 0848	- 8813E-04	- 8488E-03	8888E-03
331	88 8000	17 0141	20 0822	- 8018E-04	- 4828E-03	4888E-03

332	88 8000	18 0282	20 0803	- 1833E-03	- 2484E-03	2894E-03
333	88 8000	18 0423	20 0882	- 1714E-04	- 3781E-03	3788E-03
334	88 8000	20 0888	20 0884	- 2788E-03	- 2884E-03	3883E-03
335	72 7800	- 2 8483	20 0813	- 7380E-03	- 2888E-04	7384E-03
336	72 7800	3 8388	20 0792	- 7123E-03	- 1830E-03	7307E-03
337	72 7800	8 8178	20 0717	- 8791E-03	- 3317E-03	8873E-03
338	72 7800	18 0000	20 0818	- 2878E-03	- 3104E-03	4088E-03
339	72 7800	18 0277	20 0882	- 1888E-03	- 1978E-03	2880E-03
340	72 7800	20 0883	20 0888	- 8880E-04	- 2818E-04	7484E-04
341	78 0000	- 2 8800	20 0701	- 8474E-03	- 2892E-04	8478E-03
342	78 0000	8 8800	20 0888	- 8474E-03	- 8213E-04	8423E-03
343	78 0000	3 8800	20 0888	- 8283E-03	- 1270E-03	8318E-03
344	78 0000	8 8700	20 0880	- 8832E-03	- 1820E-03	8110E-03
345	78 0000	8 7800	20 0828	- 8327E-03	- 2318E-03	8808E-03
346	78 0000	12 8800	20 0882	- 4883E-03	- 2138E-03	8087E-03
347	78 0000	18 0000	20 0882	- 3888E-03	- 1821E-03	4218E-03
348	78 0000	17 0138	20 0884	- 3788E-03	- 1271E-03	3788E-03
349	78 0000	18 0271	20 0848	- 3871E-03	- 7872E-04	3788E-03
350	78 0000	18 0407	20 0848	- 3708E-03	- 8388E-04	3783E-03
351	78 0000	20 0842	20 0842	- 3740E-03	- 8888E-06	3741E-03
352	77 0000	- 2 8880	20 0889	- 8240E-03	- 2103E-04	8244E-03
353	77 0000	3 8387	20 0884	- 8088E-03	- 1197E-03	8178E-03
354	77 0000	8 7883	20 0802	- 8288E-03	- 2173E-03	8717E-03
355	77 0000	18 0000	20 0841	- 4188E-03	- 1840E-03	4444E-03
356	77 0000	18 0282	20 0830	- 3832E-03	- 8332E-04	4019E-03
357	77 0000	20 0824	20 0828	- 3720E-03	- 8411E-08	3721E-03
358	78 0000	- 2 7300	20 0838	- 8021E-03	- 1848E-04	8024E-03
359	78 0000	3 8117	20 0838	- 8878E-03	- 4488E-04	8888E-03
360	78 0000	8 8133	20 0824	- 8884E-03	- 1107E-03	8888E-03
361	78 0000	8 8380	20 0803	- 8878E-03	- 1888E-03	8784E-03
362	78 0000	8 7887	20 0878	- 8288E-03	- 1878E-03	8888E-03
363	78 0000	12 8783	20 0848	- 4830E-03	- 1781E-03	5148E-03
364	78 0000	18 0000	20 0820	- 4483E-03	- 1388E-03	4888E-03
365	78 0000	17 0128	20 0814	- 4387E-03	- 1037E-03	4488E-03
366	78 0000	18 0283	20 0808	- 4278E-03	- 8838E-04	4332E-03
367	78 0000	18 0378	20 0808	- 4184E-03	- 4280E-04	4218E-03
368	78 0000	20 0808	20 0808	- 4184E-03	- 4084E-06	4184E-03
369	81 2800	- 2 8438	20 0848	- 8381E-03	- 1838E-04	8384E-03
370	81 2800	3 8378	20 0834	- 8312E-03	- 8423E-04	8388E-03
371	81 2800	8 7187	20 0482	- 8080E-03	- 1788E-03	8348E-03
372	81 2800	18 0000	20 0441	- 8178E-03	- 1403E-03	8388E-03
373	81 2800	18 0208	20 0431	- 8312E-03	- 8324E-04	8378E-03
374	81 2800	20 0418	20 0428	- 8840E-03	- 7800E-06	8841E-03
375	84 8000	- 2 8878	20 0483	- 4820E-03	- 1714E-03	4823E-03
376	84 8000	8 8021	20 0482	- 4818E-03	- 3337E-04	4820E-03
377	84 8000	3 8617	20 0482	- 4788E-03	- 8317E-04	4820E-03
378	84 8000	8 8804	20 0412	- 4788E-03	- 1722E-03	8088E-03
379	84 8000	12 8404	20 0382	- 8233E-03	- 1812E-03	8872E-03
380	84 8000	18 0000	20 0382	- 8883E-03	- 1811E-03	8261E-03
381	84 8000	17 0041	20 0343	- 8333E-03	- 1488E-03	8880E-03
382	84 8000	18 0182	20 0337	- 8618E-03	- 8023E-04	8888E-03
383	84 8000	18 0244	20 0330	- 8087E-03	- 1170E-03	8188E-03
384	84 8000	20 0328	20 0328	- 8222E-03	- 8848E-04	8233E-03
385	87 0000	- 3 0480	20 0408	- 4448E-03	- 1888E-04	4448E-03
386	87 0000	3 3033	20 0388	- 4428E-03	- 7881E-04	4494E-03
387	87 0000	8 8817	20 0384	- 4413E-03	- 1772E-03	4788E-03
388	87 0000	18 0000	20 0278	- 8747E-03	- 3243E-03	8899E-03
389	87 0000	18 0041	20 0244	- 7728E-03	- 3887E-03	8888E-03
390	87 0000	20 0182	20 0231	- 1301E-02	- 1814E-03	1310E-02
391	88 8000	- 3 1228	20 0382	- 4089E-03	- 1807E-04	4092E-03
392	88 8000	0882	20 0381	- 4082E-03	- 2884E-04	4093E-03
393	88 8000	3 2480	20 0342	- 4082E-03	- 7302E-04	4117E-03
394	88 8000	8 4338	20 0327	- 3988E-03	- 1288E-03	4180E-03
395	88 8000	8 8228	20 0302	- 3888E-03	- 1738E-03	4288E-03
396	88 8000	12 8113	20 0288	- 4088E-03	- 2884E-03	8043E-03

401	80 5000	20 0000	20 0000	- 1188E-02	- 1818E-02	2181E-02
402	80 2500	-3 188E	20 0337	- 3888E-03	- 1483E-04	3881E-03
403	80 2500	3 227E	20 0327	- 3848E-03	- 7073E-04	4008E-03
404	80 2500	8 813E	20 028A	- 3748E-03	- 1872E-03	4108E-03
405	80 2500	18 0000	20 0182	- 3888E-03	- 4708E-03	5883E-03
406	80 2500	18 0000	20 0125	- 3881E-03	- 8488E-03	9332E-03
407	80 2500	20 0000	20 0000	- 2274E-12	- 1682E-02	1682E-02
408	81 0000	-3 188E	20 0322	- 3878E-03	- 1287E-04	3880E-03
409	81 0000	0 125E	20 0321	- 3883E-03	- 2788E-04	3872E-03
410	81 0000	3 2100	20 0313	- 3823E-03	- 8884E-04	3888E-03
411	81 0000	8 427E	20 0288	- 3872E-03	- 1208E-03	3888E-03
412	81 0000	8 8080	20 0274	- 3888E-03	- 1688E-03	3818E-03
413	81 0000	12 802E	20 0239	- 3118E-03	- 2417E-03	4287E-03
414	81 0000	18 0000	20 0180	- 2218E-03	- 4883E-03	8078E-03
415	81 0000	17 0000	20 0182	- 1383E-03	- 8838E-03	8883E-03
416	81 0000	18 0000	20 0118	- 2788E-04	- 7818E-03	7821E-03
417	81 0000	19 0000	20 0088	- 2018E-03	- 1148E-02	1188E-02
418	81 0000	20 0000	20 0000	- 4238E-03	- 1241E-02	1311E-02
419	88 0000	-3 3800	20 0232	- 3348E-03	- 1188E-04	3381E-03
420	88 0000	3 0380	20 0225	- 3283E-03	- 6188E-04	3304E-03
421	88 0000	8 4300	20 0188	- 2832E-03	- 1233E-03	3080E-03
422	88 0000	18 8280	20 0148	- 1377E-03	- 2081E-03	2478E-03
423	88 0000	17 8180	20 0134	- 1383E-04	- 2288E-03	2303E-03
424	88 0000	20 0081	20 0134	- 2034E-03	- 1128E-03	2324E-03
425	101 0000	-3 5280	20 0184	- 2852E-03	- 8784E-05	2854E-03
426	101 0000	- 337E	20 0184	- 2828E-03	- 1102E-04	2828E-03
427	101 0000	2 8600	20 0181	- 2784E-03	- 3087E-04	2773E-03
428	101 0000	8 087E	20 0148	- 2588E-03	- 4848E-04	2834E-03
429	101 0000	8 2880	20 0135	- 2387E-03	- 8178E-04	2447E-03
430	101 0000	12 432E	20 0124	- 2037E-03	- 8187E-04	2128E-03
431	101 0000	18 8600	20 0118	- 1882E-03	- 2882E-04	1738E-03
432	101 0000	18 7400	20 0112	- 1731E-03	- 4748E-04	1788E-03
433	101 0000	18 8301	20 0110	- 1848E-03	- 9088E-05	1851E-03
434	101 0000	18 8201	20 0108	- 2388E-03	- 7438E-04	2471E-03
435	101 0000	18 8201	20 0102	- 2818E-03	- 8807E-04	2818E-03
436	110 5000	-3 887E	20 0027	- 2544E-03	- 8217E-05	2548E-03
437	110 5000	2 527E	20 0027	- 2488E-03	- 8882E-05	2488E-03
438	110 5000	6 922E	20 0023	- 2334E-03	- 2138E-04	2344E-03
439	110 5000	18 317E	20 0018	- 2131E-03	- 1883E-04	2138E-03
440	110 5000	17 8881	20 0018	- 2078E-03	- 1338E-04	2078E-03
441	110 5000	20 0007	20 0018	- 1888E-03	- 7071E-05	1888E-03
442	120 0000	-4 2000	18 8912	- 2318E-03	- 8008E-05	2318E-03
443	120 0000	-1 002E	18 8913	- 2318E-03	- 8104E-05	2318E-03
444	120 0000	2 1850	18 8914	- 2308E-03	- 3638E-05	2308E-03
445	120 0000	5 392E	18 8914	- 2302E-03	- 1018E-06	2302E-03
446	120 0000	8 5900	18 8914	- 2294E-03	- 8551E-06	2294E-03
447	120 0000	11 787E	18 8913	- 2280E-03	- 2188E-05	2280E-03
448	120 0000	14 8850	18 8913	- 2280E-03	- 8703E-06	2280E-03
449	120 0000	18 238E	18 8913	- 2280E-03	- 1508E-06	2280E-03
450	120 0000	17 8881	18 8913	- 2301E-03	- 1400E-05	2301E-03
451	120 0000	18 8317	18 8913	- 2323E-03	- 8832E-05	2323E-03
452	120 0000	18 8812	18 8912	- 2341E-03	- 2283E-05	2341E-03
453	132 3800	-4 832E	18 8770	- 2278E-03	- 7438E-05	2278E-03
454	132 3800	1 782E	18 8772	- 2272E-03	- 6727E-05	2272E-03
455	132 3800	5 878E	18 8773	- 2281E-03	- 2182E-06	2281E-03
456	132 3800	14 852E	18 8774	- 2248E-03	- 7032E-06	2248E-03
457	132 3800	17 2651	18 8774	- 2248E-03	- 1137E-06	2248E-03
458	132 3800	18 8774	18 8774	- 2240E-03	- 3580E-06	2240E-03
459	144 7000	-8 084E	18 8831	- 2214E-03	- 7482E-06	2214E-03
460	144 7000	-1 8870	18 8832	- 2218E-03	- 8831E-06	2220E-03
461	144 7000	1 330E	18 8833	- 2218E-03	- 8870E-06	2220E-03
462	144 7000	4 5280	18 8834	- 2221E-03	- 4838E-06	2221E-03

464	144 7000	7 728E	18 8834	- 2222E-03	- 3870E-06	2222E-03
465	144 7000	10 8230	18 8835	- 2223E-03	- 2738E-06	2223E-03
466	144 7000	14 120E	18 8835	- 2223E-03	- 2074E-06	2223E-03
467	144 7000	18 861E	18 8835	- 2224E-03	- 1443E-06	2224E-03
468	144 7000	17 0420	18 8835	- 2224E-03	- 1288E-06	2224E-03
469	144 7000	18 802E	18 8836	- 2228E-03	- 3284E-06	2228E-03
470	144 7000	18 8838	18 8838	- 2228E-03	- 8874E-06	2228E-03
471	178 8800	-8 284E	18 8248	- 2121E-02	- 7347E-06	2123E-02
472	178 8800	1 002E	18 8281	- 2123E-03	- 8874E-06	2123E-03
473	178 8800	6 488E	18 8282	- 2124E-03	- 3832E-06	2124E-03
474	178 8800	12 880E	18 8283	- 2124E-03	- 2101E-06	2124E-03
475	178 8800	18 408E	18 8284	- 2124E-03	- 1144E-06	2124E-03
476	178 8800	18 8282	18 8284	- 2124E-03	- 1820E-06	2124E-03
477	215 0000	-7 5280	18 8884	- 2030E-03	- 7147E-06	2031E-03
478	215 0000	-4 327E	18 8885	- 2028E-03	- 8887E-06	2030E-03
479	215 0000	-1 1300	18 8888	- 2028E-03	- 8800E-06	2028E-03
480	215 0000	2 087E	18 8887	- 2028E-03	- 4337E-06	2028E-03
481	215 0000	5 2850	18 8887	- 2027E-03	- 4018E-06	2027E-03
482	215 0000	8 483E	18 8888	- 2027E-03	- 2874E-06	2028E-03
483	215 0000	11 8800	18 8888	- 2028E-03	- 3274E-06	2028E-03
484	215 0000	13 717E	18 8888	- 2028E-03	- 1818E-06	2028E-03
485	215 0000	15 7744	18 8888	- 2028E-03	- 1283E-06	2028E-03
486	215 0000	17 8317	18 8888	- 2028E-03	- 8311E-06	2028E-03
487	215 0000	18 8888	18 8888	- 2028E-03	- 2231E-06	2028E-03
488	253 0000	-8 8880	18 8807	- 1930E-03	- 8134E-06	1831E-03
489	253 0000	-2 4800	18 8809	- 1935E-03	- 4848E-06	1836E-03
490	253 0000	3 8380	18 8810	- 1940E-03	- 3204E-06	1840E-03
491	253 0000	10 3300	18 8811	- 1942E-03	- 1938E-06	1843E-03
492	253 0000	15 0810	18 8812	- 1944E-03	- 1048E-06	1844E-03
493	253 0000	18 8818	18 8812	- 1944E-03	- 1178E-06	1844E-03
494	281 0000	-10 1880	18 8180	- 1828E-03	- 1828E-06	1828E-03
495	281 0000	-6 987E	18 8180	- 1833E-03	- 8882E-14	1833E-03
496	281 0000	-3 7800	18 8180	- 1841E-03	- 1028E-06	1841E-03
497	281 0000	8 882E	18 8180	- 1848E-03	- 5888E-14	1848E-03
498	281 0000	2 8080	18 8180	- 1852E-03	- 7019E-06	1852E-03
499	281 0000	5 802E	18 8180	- 1858E-03	- 4882E-14	1858E-03
500	281 0000	8 0000	18 8180	- 1861E-03	- 4027E-06	1861E-03
501	281 0000	11 703E	18 8180	- 1864E-03	0	1864E-03
502	281 0000	14 407E	18 8180	- 1868E-03	0	1868E-03
503	281 0000	17 111E	18 8180	- 1868E-03	0	1868E-03
504	281 0000	18 8180	18 8180	- 1867E-03	- 1488E-06	1867E-03

SEMPAGE PAGE COMPUTATION RESULTS

NO :	98	NO :	113	AVE. VEL :	8880E-01	DS :	18000E+01	DO :	10488E+00	#1 Trench g1
TOTAL DISCHARGE :										10488E+00
NO :	113	NO :	188	AVE. VEL :	4880E-01	DS :	28000E+02	DO :	11488E+01	#2 Trench g2
TOTAL DISCHARGE :										12837E+01
NO :	188	NO :	215	AVE. VEL :	23288E-01	DS :	18000E+01	DO :	34842E+01	#3 Trench g3
TOTAL DISCHARGE :										12887E+01
NO :	215	NO :	300	AVE. VEL :	18280E-01	DS :	28000E+02	DO :	38850E+00	#4 Trench g4
TOTAL DISCHARGE :										18482E+01
NO :	300	NO :	317	AVE. VEL :	71801E-02	DS :	18000E+01	DO :	10728E+01	#4 Trench g4
TOTAL DISCHARGE :										18888E+01
NO :	317	NO :	402	AVE. VEL :	82404E-02	DS :	25000E+02	DO :	10801E+00	
TOTAL DISCHARGE :										17818E+01
NO :	402	NO :	418	AVE. VEL :	17382E-02	DS :	18000E+01	DO :	28643E-02	
TOTAL DISCHARGE :										17848E+01

"End of Problem"

APPENDIX C
DISCRIPTION OF COMPUTER PROCEDURES

APPENDIX C

APPENDIX C

Using a Personal Computer in Running the Aral Seepage Program

I. Introduction:

The Aral Seepage Program is located on the Georgia Institute of Technology main frame computer in the Cyber B area. To run many runs of the program it is very convenient to prepare and edit the data files on a personal computer, using an editor or word processor. A brief description of the method for this particular program follows. A user should get instruction and information for use of the Cyber B from the Office of Computer Services, Rich Building, Georgia Institute of Technology.

II. Preparing the Data Files:

Using the Aral Seepage Program User's Manual (Pirtle, Appendix A) draw and label the mesh for the problem to be run. An example is Figure 3-5 of this study, but a working copy of the mesh should be large enough for easy referral and use. With the mesh and a complete list of problem characteristics a data file can be prepared, from the user's manual instructions.

In this study the number of nodes and basic shape of the mesh was to be unchanged for all of the runs. To

simplify preparing the data files a spreadsheet was prepared. Changing the dimensions or hydraulic conductivities (vertical or horizontal) required one entry and the spreadsheet adjusted the node positions from simple formulas. The complexity of the spreadsheet is entirely dependent on the problem considered and the skill of the user with a spreadsheet program. Any of the commercially available programs will work satisfactorily. If the study will involve several different mesh arrangements and/or only a few runs the data file can more easily be prepared on an editor by typing it in, if the editor is set to create an ASCII file.

An ASCII file is a file of the characters as entered. Word processing programs and spreadsheet programs have hidden command codes which control the programs so that the features are executed. Features are the calculation of values in a spreadsheet or the margins, justification and format of a word processor.

Most spreadsheet programs have a function or ancillary utility program for conversion of the spreadsheet to a values separated by commas ASCII format. With that utility the spreadsheet no longer will do calculations or have the simple column alignment.

In this study the programs available provided an ASCII file with all values separated by commas. The file did have commas to separate what had been empty cells

within the spreadsheet. Other programs may not have that result. To delete the commas a word processor was used. A program which allows editing an ASCII file is necessary for this operation. If a word processor is used in the normal mode of edit command codes will be imbedded to set margins and the file will not run properly on the Aral Seepage Program.

III. Sending the Data File:

With a proper data file prepared running the Aral Seepage Program from a personal computer requires one device and several clearances. An authorization to use the Cyber B must be obtained, with a file storage area, a password and an identification code. This is explained by manuals available at the Office of Computer Services. Access to the Aral Seepage Program, named OWRCC must now be obtained from the School of Civil Engineering at the Mason Building. The device needed is a MODEM for transfer of data and commands to the Cyber B. The speed and manufacture of the MODEM is subject to the needs of the user.

A communications program is necessary to use the MODEM and many such programs are available. Georgia Tech offers students and faculty a program named COGITATE for use in communicating. In this study a different program was used but, it had the KERMIT file transfer program and

this is necessary.

With the communications program call the GTNET system and when a connection is made enter the GTNET command:

```
>> Connect *OCS CYBER B
```

A connection to this directory will be made and right to access will be challenged:

```
Family  CYBERB
```

```
Userid  (input the assigned ID)
```

```
Password (input the selected password)
```

Access will be granted to the Cyber B area. To copy the data file to your file for execution of the Aral Seepage Program the program COGITATE has menu entries to execute. If another communication program is used the KERMIT protocol is necessary. The details of this description are better left to someone else. In this study the following procedure worked.

```
\ KERMIT2
```

Control was now with the user's computer by use of KERMIT commands. Executing the "Send" command of KERMIT and naming the data file to be downloaded successfully transferred the file. The file name was changed as the cyber will use the first eight alpha-numeric characters of the name and ignore any periods normally used to separate suffixes in the MS-DOS environment. At the completion of sending data files execute the KERMIT command to "Finish" and control will be re-established

with the Cyber.

IV. Running the Program:

To run the program and receive a printed output from the laser printers in the Rich Building do the following:

\ OLD,OWRCC

\ GET,DATA (note:DATA is data file as named upon receipt by Cyber. To see names answer \ with LF)

\ OWRCC,DATA,PRINT (note:PRINT is name selected for the output by user. If no print is specified the output of the run will go to the screen. With a MODEM this is a very long process and is not recommended.)

A short wait of less than a minute can normally be expected here. If an error message is received the data file should be checked for errors in concept and tried again. If a transfer error is suspected send the file a second time.

\ SAVE,PRINT (note:SAVE only if a copy of the output is desired for the holding on Cyber)

\ PRINT? (note:A hard copy of the program output will be received in the Rich Building if the output file name PRINT is input at the first query and all other entries are allowed to default by responding with the "ENTER" or "RETURN" key. The last query asks for the USERID and responding with the ID has it printed on the cover of the hard copy for easier identification.

There are several other printer locations and many options one can exercise in printing the results. For more information consult the advisors in the Rich Building.

To exit from the Cyber:

```
\ LOGOUT  
>> LOGOUT
```

V. Caution:

This appendix is not a replacement for the user's manuals of the programs used, nor for the instructions and guidance of the Office of Computer Services. It is a quick and easy guide of a procedure that has been successful in running programs on the Aral Seepage Program.

As stressed above many different programs will do the functions of the above procedure. For information the following were used:

Spreadsheet: SuperCalc 3

Editor: WordStar 4.0

Communications: ProComm 2.1

It would be an advantage if the output file from the Aral Seepage Program could be captured and downloaded from the Cyber. This was attempted with KERMIT once but, was discontinued after twenty minutes of transfer with a 1200 Baud MODEM.

APPENDIX D
SPREADSHEET AND DATA FILE DISKS

APPENDIX D

APPENDIX E
ARBITRARY SELECTION OF RADIUS

APPENDIX E

APPENDIX E

Arbitrary Selection of Radius

In this study the radius of influence was determined as the distance at which no more than a 10% decrease in total flow over a 100 foot change in trial radii occurs. This arbitrary selection is certainly open to discussion. It is very common for less restrictive criteria to be used in the definition of radius of influence of drawdown.

Figures E-1 and E-2 are cross section drawings of the free water surface in the trench area if the radius of influence had been selected at lower values based on some different arbitrary standard. Obviously the free surface reaches the upper blanket and possibly the foundation. The formulas used in Chapter 4 were based on field data of seepage and the field interpretation of the radius of influence, under some standard determination.

If the selection of radius of influence for this study had been based on a different criteria the predictive forms and dimensionless products would have been changed. Using a standard of $0.1 \text{ ft}^3/\text{day}/\text{ft}$, maximum change in trial radii of influence, Criteria A, results in Figures E-3 and E-4. These figures are the dimensionless product for a different standard of radius of influence. The new standard is on average $0.07 \text{ ft}^3/\text{day}/\text{ft}$ less restrictive and predict the radii of

TABLE E-1

SUMMARY OF DATA, CRITERIA A RADIUS DETERMINATION

Slope	Sp	Hr	h	Li' (ft)	q' ft ² /day	F' (ft)
0	15	20	10	250	0.18	0.28
0	25	20	10	250	0.15	0.31
0	35	20	10	250	0.15	0.36
0	15	20	20	400	0.25	0.4
0	25	20	20	400	0.22	0.45
0	35	20	20	350	0.22	0.58
0	15	60	10	350	0.22	0.45
0	25	60	10	300	0.21	0.65
0	35	60	10	300	0.2	0.75
0	15	60	20	450	0.35	0.76
0	25	60	20	450	0.32	0.93
0	35	60	20	450	0.3	1.05
3.5	15	20	10	200	0.2	0.48
3.5	25	20	10	100	0.21	0.73
3.5	35	20	10			
3.5	15	20	20	400	0.25	0.6
3.5	25	20	20	250	0.25	0.95
3.5	35	20	20	300	0.25	0.98
3.5	15	60	10	300	0.21	0.65
3.5	25	60	10	200	0.24	1.1
3.5	35	60	10	150	0.25	1.4
3.5	15	60	20	450	0.32	0.92
3.5	25	60	20	425	0.3	1.27
3.5	35	60	20	400	0.3	1.55
7	15	20	10	100	0.3	0.81
7	25	20	10			
7	35	20	10			
7	15	20	20	225	0.38	0.98
7	25	20	20	175	0.39	1.25
7	35	20	20	125	0.39	1.85
7	15	60	10	150	0.3	1.05
7	25	60	10	75	0.38	1.8
7	35	60	10	50	0.4	2.1
7	15	60	20	350	0.38	1.21
7	25	60	20	300	0.39	1.8
7	35	60	20	225	0.41	2.42

Table E-1. The new curves of dimensionless products in Figures E-3 and E-4 show the less restrictive curves to be nearly unchanged.

As a further check a second standard, Criteria B was developed. This standard is defined as a total flow increase of 75% from the total flow at a trial radius of 700 feet. The scatter plot of the dimensionless product versus total flow and maximum free surface is shown by Figures E-5 and E-6 for Criteria A and Criteria B. Table E-7 summarizes the results of Criteria B.

Figures E-7 and E-8 show the final curves for total flow and the maximum free surface against the dimensionless product for all considered standards. The curves are little changed. The use of one composite curve would suffice in predicting total flow and maximum free surface for any standard of radii determination.

An incorrect radius of influence will under predict the flow and maximum free surface if too high. A conservative approach would be to reduce the radius of influence as predicted from Figures 4-1,2 and 3. The amount of adjustment would require additional field data from a trench drain system.

FREE SURFACE PROFILE

Slope = 0%, L = 200', Spacing = 25'

H = 60', h = 20'

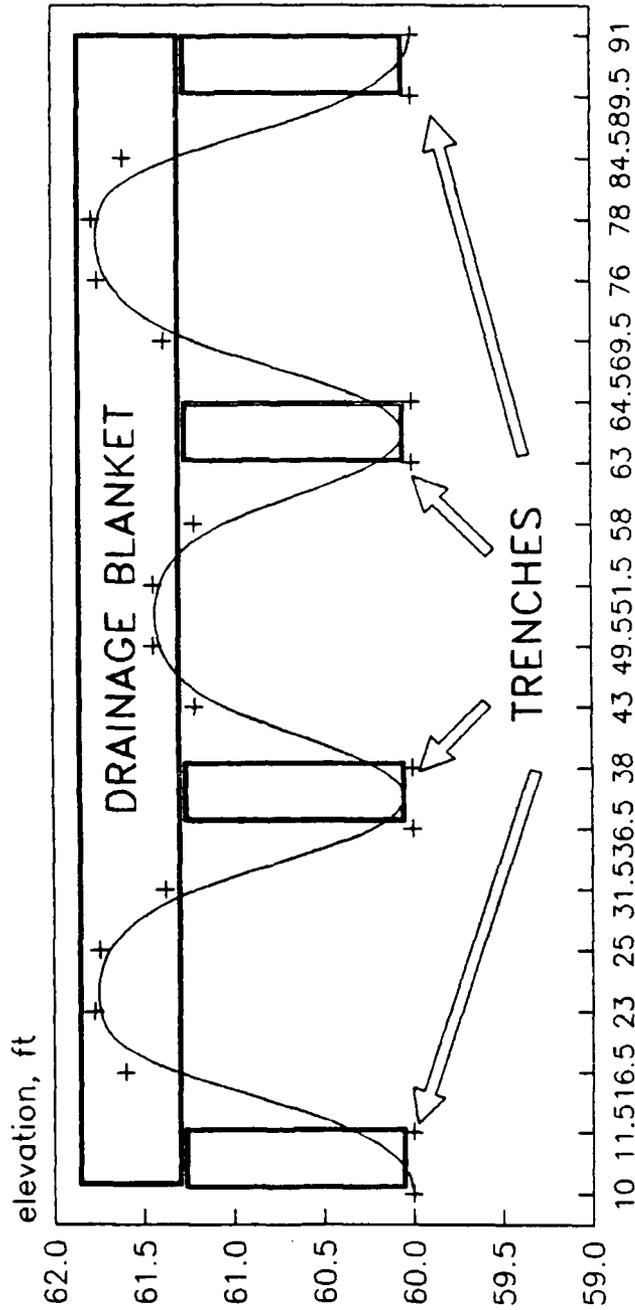
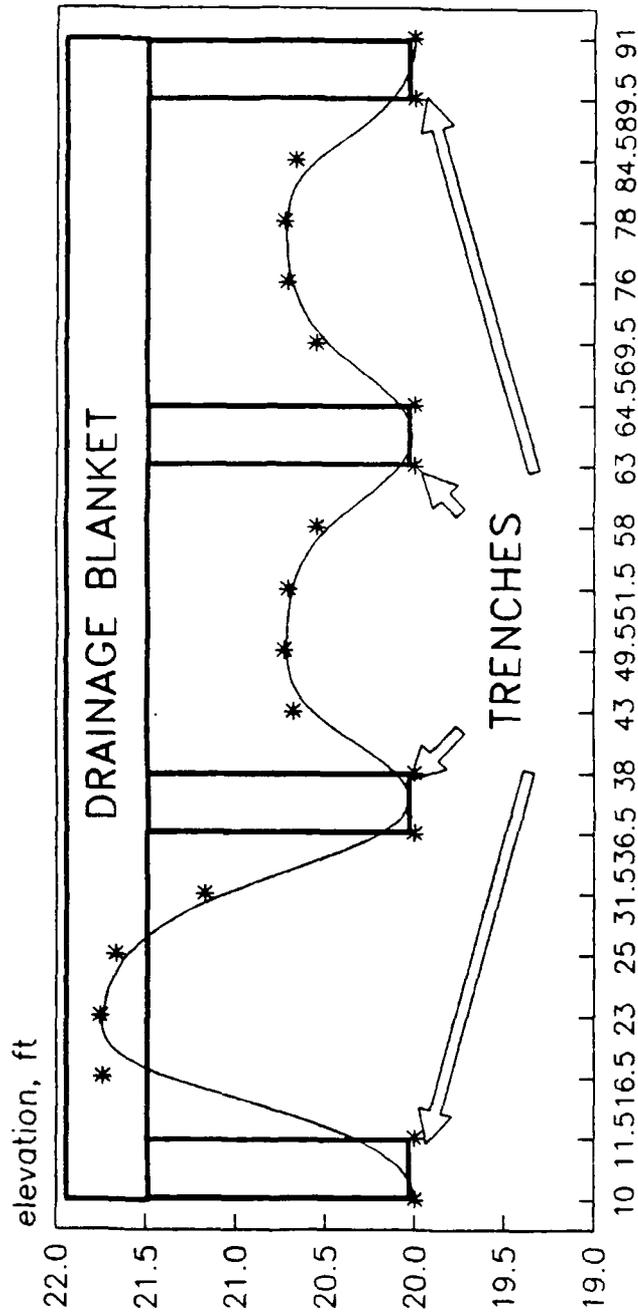


Fig. E-1
Free surface between trenches

FREE SURFACE PROFILE

Slope = 7%, L = 100', Spacing = 25'

H = 20', h = 20'



lateral position within trench area

Fig. E-2
Free surface between trenches

TABLE E-2

SUMMARY OF DATA, CRITERIA B RADIUS DETERMINATION

Slope	Sp	Hr	h	L1' (ft)	q' ft ² /day	F' (ft)
0	15	20	10	325	0.12	0.26
0	25	20	10	400	0.1	0.21
0	35	20	10	500	0.09	0.16
0	15	20	20	400	0.26	0.4
0	25	20	20	375	0.23	0.46
0	35	20	20	375	0.21	0.65
0	15	60	10	400	0.19	0.44
0	25	60	10	425	0.18	0.6
0	35	60	10	400	0.18	0.7
0	15	60	20	400	0.4	0.8
0	25	60	20	375	0.39	1.05
0	35	60	20	400	0.35	1.15
3.5	15	20	10	200	0.19	0.48
3.5	25	20	10	100	0.19	0.73
3.5	35	20	10			
3.5	15	20	20	350	0.28	0.75
3.5	25	20	20	200	0.25	1.05
3.5	35	20	20	300	0.25	0.98
3.5	15	60	10	225	0.26	0.85
3.5	25	60	10	225	0.23	1.05
3.5	35	60	10	100	0.26	1.5
3.5	15	60	20	400	0.37	1.05
3.5	25	60	20	375	0.35	1.5
3.5	35	60	20	325	0.33	1.7
7	15	20	10			
7	25	20	10			
7	35	20	10			
7	15	20	20	175	0.45	1.3
7	25	20	20	150	0.47	1.5
7	35	20	20	100	0.52	2
7	15	60	10	125	0.35	1.3
7	25	60	10			
7	35	60	10			
7	15	60	20	300	0.45	1.4
7	25	60	20	225	0.49	1.95
7	35	60	20	150	0.56	3

TOTAL FLOW

(Four trench drains, 0 to 7% slope,
 $K_v = Kh$, trench width 1.5')

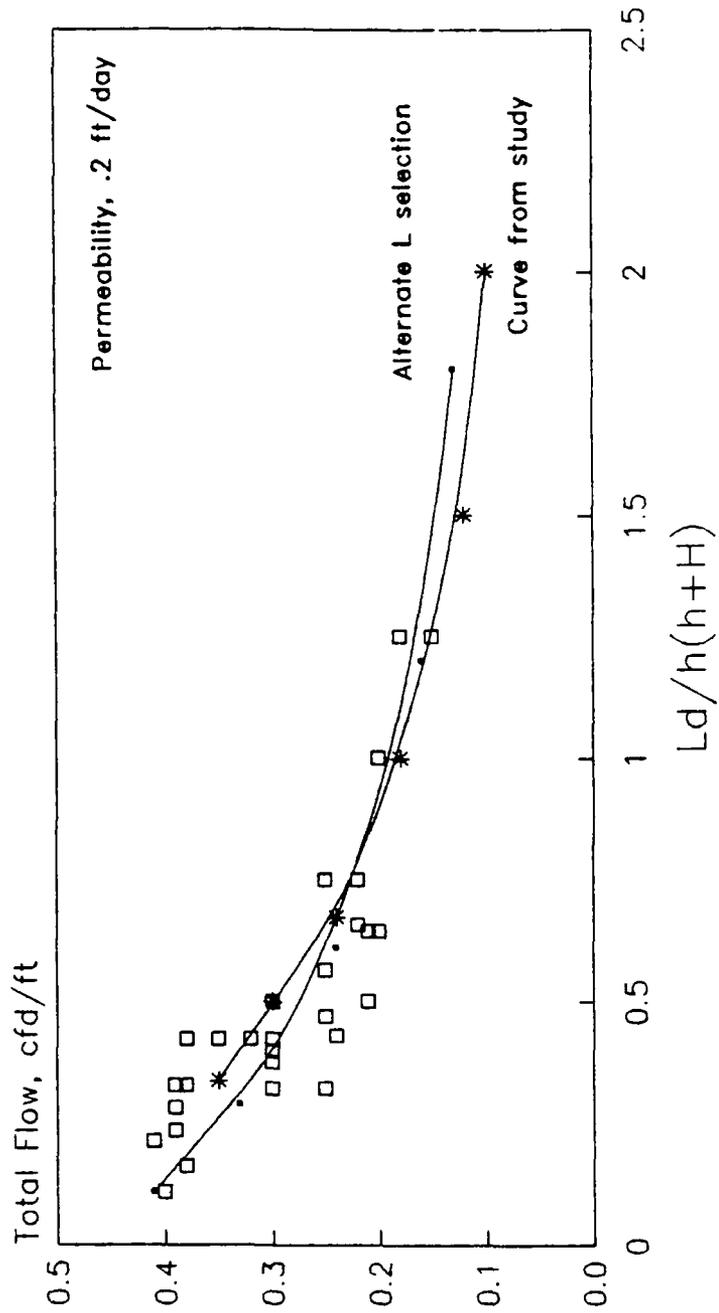


Fig. E-3
Radius selected from alternate method

Max Free Surface

(Four trench drains, Slope 0 to 7%
 $K_v = Kh$, trench width 1.5')

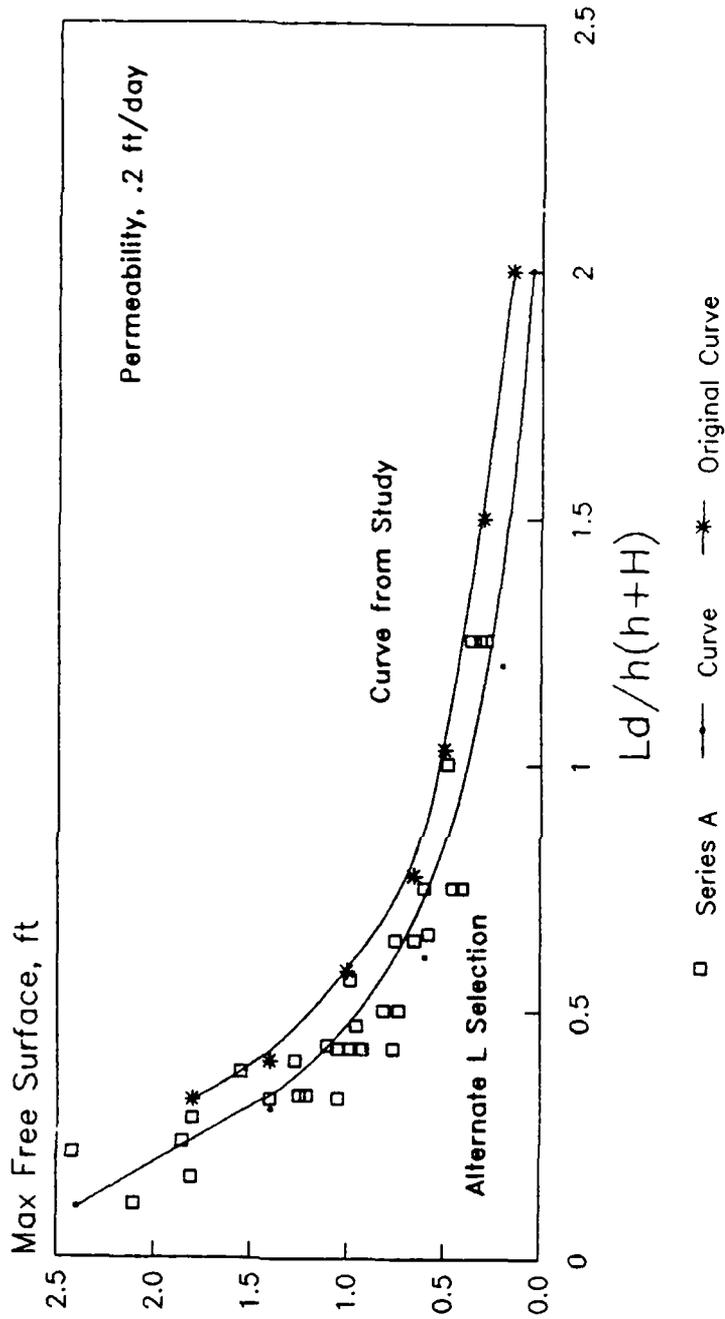


Fig. E-4
 Selection of L from alternate method

Total Flow

Radius from alternate methods

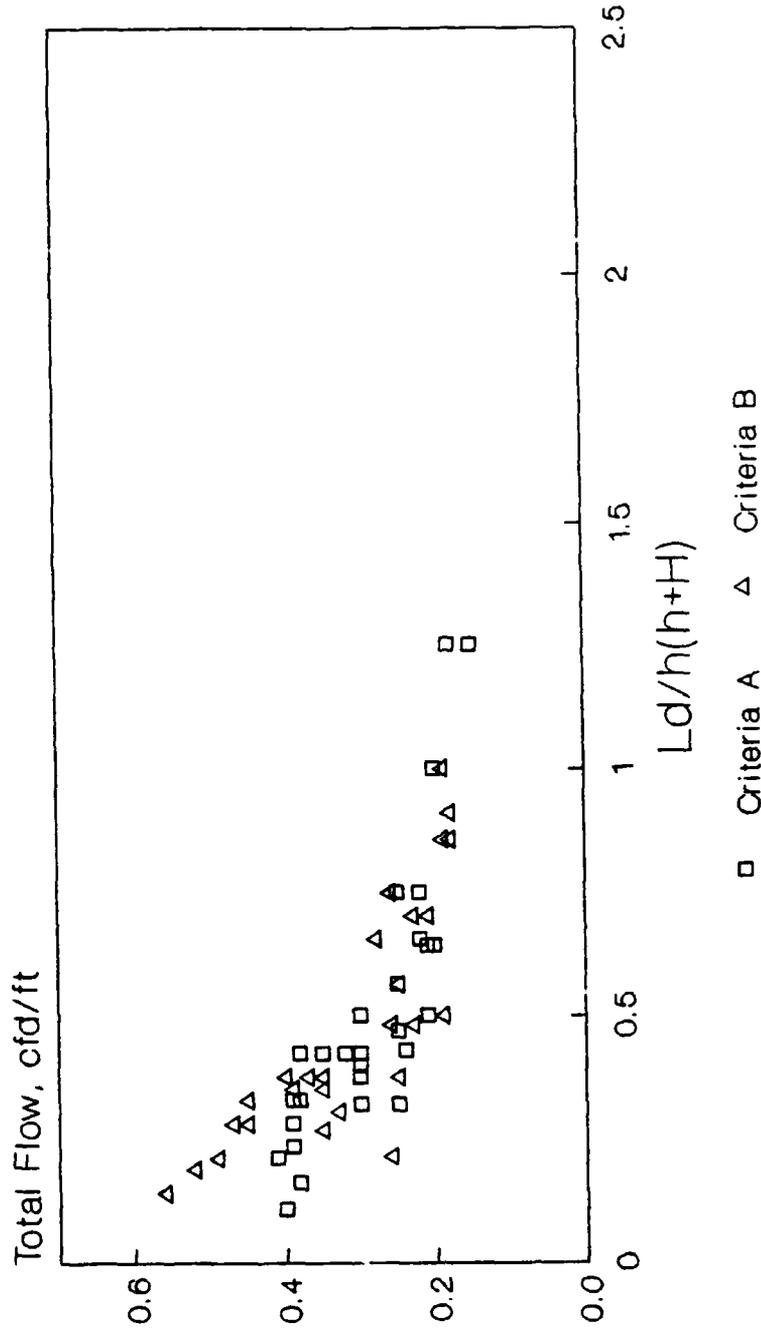


Fig E-5
Comparison of two alternate
criteria for radii determination

Max Free Surface

Radius from alternate method

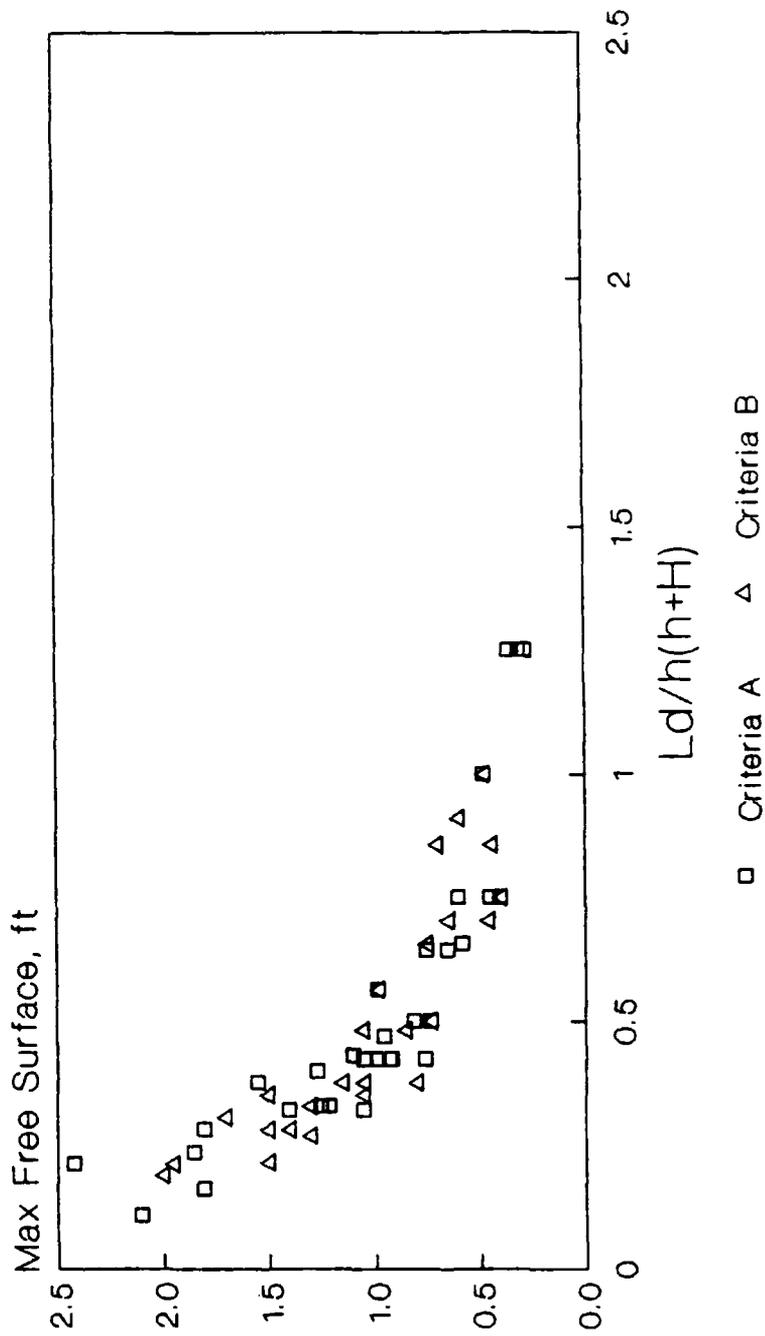


Fig. E-6
Comparison of two alternate
criteria for radii determination

Total Flow

Dimensionless Comparison
from all radii determinations

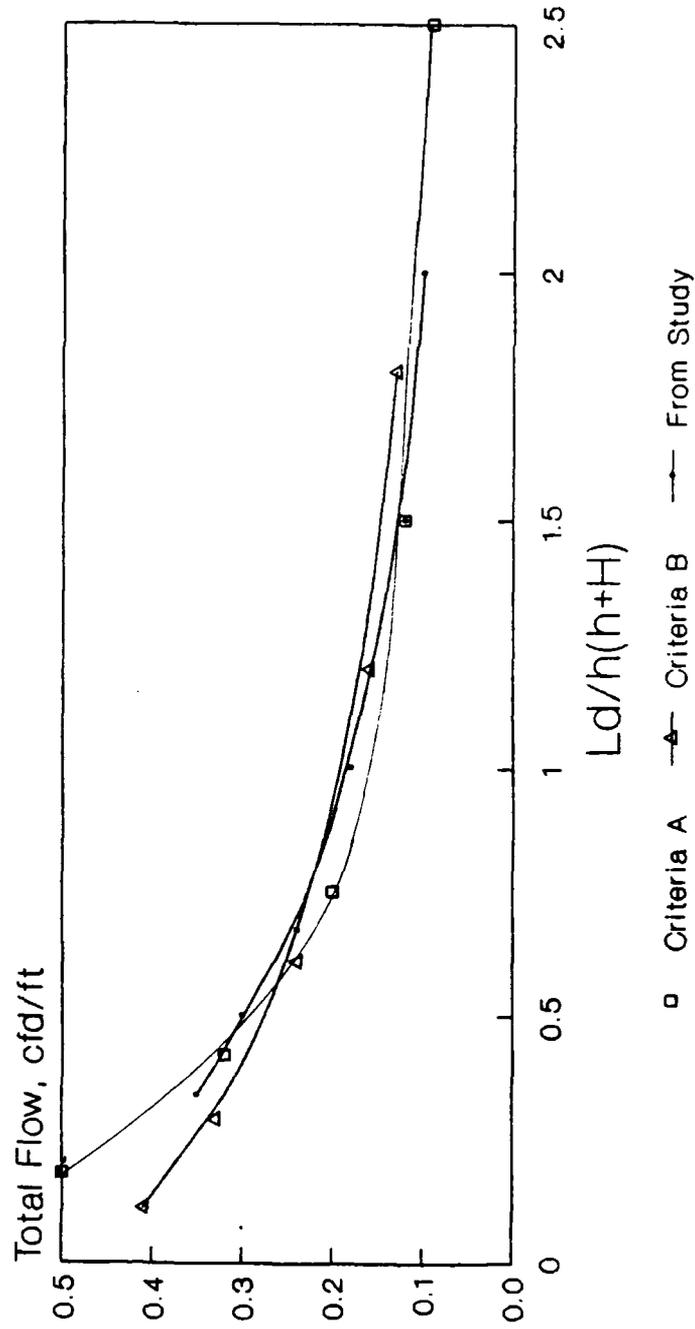


Fig. E-7
Primary and two alternate
radii determination methods

Maximum Free Surface

Dimensionless Comparison
from all radii determinations

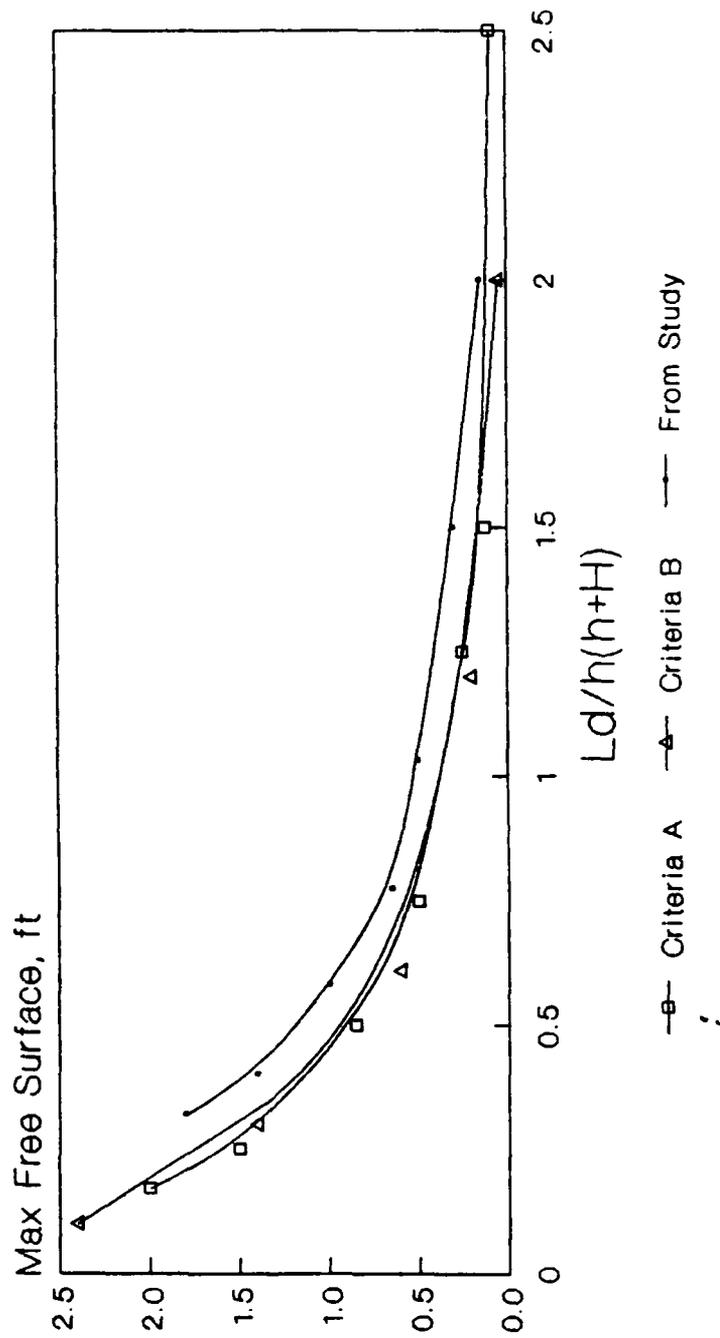


Fig. E-8
Primary and two alternate
radii determination methods